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ANALYSIS OF THE JUNE 5, 1989, UF_6 RELEASE TEST

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CONTENTS

FIGURES

FIGURES (continued)

TABLES

TABLES (continued)

1. INTRODUCTION

A series of controlled uranium hexafluoride (UF_6) release tests was conducted at a French government test site near Bordeaux, France. The results of the first release test are documented in report by R.A. Just (Just, 1986). The first UF_6 release test was designated as a qualification test. The primary objective of this test was to provide the information required to obtain approval for a series of UF_6 release tests. A second release test was conducted on April 10, 1987 (Just and Bloom, 1989). During the second release, 146.2 kg of UF_6 vapor was released over a time interval of 30 min 5 s from a 3.15-m-high, 0.05-m-diam pipe. Information collected during the second release test included meteorological data, measurements of uranium and fluorine concentrations, particle size distribution information, deposition data, and visual data (photographs and a videotape).

A third release test was conducted on June 5, 1989, during which 73.1 kg of UF_6 vapor was released over an interval of 15 min. The information collected was similar to the second release and also included temperature measurements within the plume close to the release point. Data from this third release test were provided to the U.S. Department of Energy (DOE) and Martin Marietta Energy Systems, Inc., in a report by C. Geisse (Geisse, 1989), and a videotape, *EURODIF, LACHERS UF_6* (1989). The analysis of these data is the subject of this report.

DOE sponsored the development of a UF_6 dispersion model at Energy Systems (Bloom et al., 1989), and this model has been used to simulate postulated accidental releases of UF_6. This model simulates the unique aspects of UF_6 dispersion, which include the effects of chemical reactions; positive, neutral, or negative buoyancy; phase changes; elevated or ground-hovering behavior; and significant density variations. The data from the UF_6 release tests are the only known information on UF_6 releases that can be used to evaluate the accuracy of the UF_6 dispersion model. In addition to the analysis of the data collected during the test on June 5, 1989, this report includes a comparison of these data with the predictions of the UF_6 dispersion model.

2. METEOROLOGICAL PROPERTIES

Information collected during the third release test on June 5, 1989 included meteorological data that were used in the analyses of the data and to provide input for the UF_6 dispersion model. The inputs were wind velocities and direction, temperatures, pressure, and atmospheric stability class.

2.1 METEOROLOGICAL DATA

Measured meteorological data included the following:

- 2-min average and standard deviation values of the wind velocity at 2-, 10-, 18- and 28-m elevations;
- 2-min average values of the relative humidity at 2 and 28 m;
- 2-min average values of the ambient temperature differential between 2 and 28 m;
- 2-min average values of the ambient temperature at 2 m and ground level;
- 2-min average and standard deviation values of the wind direction at 10 and 28 m; and
- 2-min average values of the ambient pressure.

These data are summarized in Table 2.1. Table 2.1 also gives the mean values of these quantities over the duration of the release (17:30 to 17:45). Since the data apply to the end of the indicated time and were reported only at 2-min intervals, the mean values are actually for the period 17:32 to 17:46.

The mean value for the period 17:32 to 17:46 is simply

$$X = \sum_{j=1}^{j=8} x_j / 8 ,$$

where

X = mean value during the period 17:32 to 17:46,
j = one of the 2-min intervals,
x_j = the value at the end of Interval j.

The standard deviation for the period 17:32 to 17:46 is given by

$$S^2 = \sum_{j=1}^{j=8} (x_j^2 + s_j^2) / 8 - X^2 ,$$

where

S = standard deviation during the period 17:32 to 17:46,
s_j = standard deviation at the end of interval j.

Table 2.1. Meteorological data during the test[a]

Time[b]	Elevation								Elevation		Temperature (°C)			Elevation				Atm pres. (hPa)
	28 m		18 m		10 m		2 m		2 m	28 m	Diff[c]	Elevation		28 m		10 m		
	Wind speed and standard deviation (m/s)								Rel Humidity (%)			2 m	Grnd	Wind direction and std. dev.				
17:30	5.7	0.2	5.2	0.2	4.8	0.2	3.8	0.2	53.6	46.3	-0.81	17.5	21.1	297.8	2.5	299.0	2.2	1021.4
17:32	4.5	0.1	4.0	0.2	3.7	0.2	3.2	0.1	54.6	47.4	-0.66	17.6	21.1	309.2	2.8	321.7	3.1	1021.5
17:34	4.7	0.1	4.6	0.1	4.1	0.1	3.6	0.1	55.1	47.0	-0.67	17.7	21.1	320.6	3.4	311.7	8.2	1021.5
17:36	5.6	0.2	5.5	0.2	4.9	0.2	4.3	0.1	55.2	46.8	-0.78	17.8	21.2	317.0	2.6	314.1	2.1	1021.5
17:38	5.2	0.1	5.0	0.2	5.0	0.2	3.9	0.1	54.1	46.6	-0.69	17.7	21.2	304.5	2.4	310.5	2.3	1021.5
17:40	5.0	0.1	4.8	0.1	4.7	0.1	3.5	0.1	53.9	47.0	-0.76	17.7	21.2	314.0	2.6	316.8	2.0	1021.5
17:42	5.4	0.1	5.2	0.2	5.4	0.2	4.6	0.2	54.2	46.7	-0.58	17.6	21.2	310.4	2.2	315.1	1.7	1021.5
17:44	5.4	0.1	5.2	0.2	4.9	0.1	4.1	0.1	54.0	46.9	-0.57	17.6	21.2	317.0	2.8	322.3	2.2	1021.5
17:46	5.8	0.1	5.7	0.2	5.3	0.2	4.5	0.2	54.1	46.6	-0.65	17.6	21.2	308.2	2.1	316.6	1.9	1021.5
17:48	6.2	0.2	6.1	0.2	5.4	0.2	4.3	0.2	54.0	46.1	-0.74	17.6	21.3	309.7	2.1	313.4	1.7	1021.5
Test	5.2	0.4	5.0	0.5	4.8	0.6	4.0	0.5	54.4	46.9	-0.67	17.7	21.2	312.6	5.7	316.1	5.3	1021.5

[a]Data are 2-min averages.
Test refers to the mean and standard deviation of the data from 17:32 through 17:46.
[b]Time is the end of the 2-min interval.
[c]Diff is the temperature at 2 m minus the temperature at 28 m.

As indicated in Table 2.1, the average wind velocity during the UF_6 release was 5.2 m/s at an elevation of 28 m, 5.0 m/s at 18 m, 4.8 m/s at 10 m, and 4.0 m/s at 2 m. The average relative humidity was 54.4% at 2 m and 46.9% at 28 m. The average value of the temperature difference between 2 and 28 m was −0.67°C. The average ambient temperature was 17.7°C at an elevation of 2 m and was 21.2°C at ground level. The mean and the standard deviation of the wind direction were 312.6° and 5.7° at 28 m elevation, and 316.1° and 5.3° at 10 m. The variation of the wind direction during the test is shown in Fig. 2.1. The atmospheric pressure was constant during the test at 1021.5 hectopascals.

Some uncertainty exists about the sign of the temperature difference between 2 and 28 m. Both the Geisse report (1989) and the Just and Bloom report (1989) indicated that the difference was the temperature at 2 m minus the temperature at 28 m, which leads to a positive ambient temperature gradient of 2.6 °C/100 m. However, the soil temperature was higher than the temperature at 2 m, which would indicate a steep negative temperature gradient close to the ground. Also, a paper reviewing the UF_6 release tests (Crabol et al., 1991) gave the ambient temperature gradient during the June 1989 test as −2.6 °C/100 m.

2.2 ATMOSPHERIC STABILITY

Criteria for evaluating atmospheric stability are presented in Tables 2.2 and 2.3. Based on the videotape of the release test, a moderate to strong insolation level can be assumed, and the information in Table 2.2 indicates that a wind velocity of approximately 4 m/s would yield a classification of "moderately unstable," or Class B stability. The standard deviation in the wind direction over the entire release is 5.3° at an elevation of 10 m and 5.7° at 28 m. The information presented in Table 2.3 indicates these data correspond to "slightly stable," or Class E stability.

There are two methods for employing the ambient temperature measurements to estimate the atmospheric stability. The simplest method is to compare the temperature gradient with Table 2.3. However, there is the uncertainty in the sign of this gradient. A gradient of 2.6 °C/100 m would indicate "moderately stable," or Class F stability, while a gradient of −2.6 °C/100 m would indicate "very unstable," or Class A stability. Because of the uncertainty in the sign of the temperature gradient, neither of these stabilities should be considered. A more complicated method is to estimate the Richardson number, which is a ratio of the buoyant force to the turbulent force. The UF_6 dispersion model estimates this number at an elevation of 10 m based on the ambient temperature input (in this case, the temperatures at ground level, 2 m, and 28 m). The value computed by the UF_6 dispersion model is either −0.46 or −0.52, depending on the sign of the temperature gradient between 2 and 28 m. According to Table 2.3, either of these values would indicate "moderately unstable," or Class B stability.

The above discussion does not lead to a clear choice of stability category. However, two of the methods indicated B stability, and Class B provided the best fit between the predictions of the UF_6 dispersion model and the data for regions near the centerline of the plume. Consequently, it is concluded that the most plausible stability category during the release was Class B.

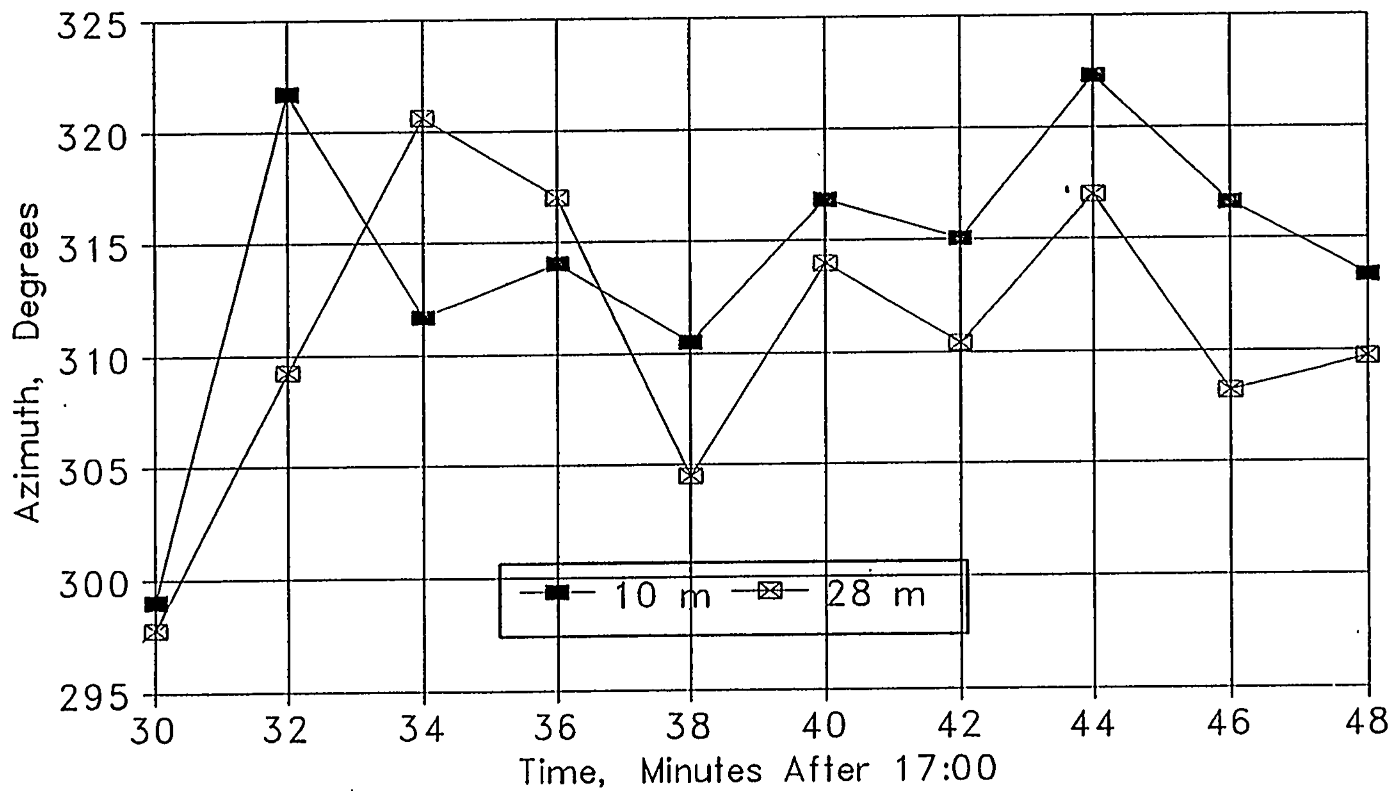

Fig. 2.1. Wind direction during test.

Table 2.2. Meteorological conditions defining Pasquill turbulence types

Surface wind speed (m/s)	Daytime insolation[a]			Nighttime conditions[a]	
	Strong	Moderate	Slight	Thin overcast or >4/8 low cloud[b]	<3/8 cloudiness[b]
<2	A	A-B	B		
2	A-B	B	C	E	F
4	B	B-C	C	D	E
6	C	C-D	D	D	D
>6	C	D	D	D	D

Source: C. Geisse, *LACHER d'UF 2[EME] ESSAI DE VALIDATION, 5 JUIN 1989, COMPTE RENDU des RESULTS*, Rapport Eurodif, 1989.

[a] A - extremely unstable conditions.
B - moderately unstable conditions.
C - slightly unstable conditions.
D - neutral conditions (applicable to heavy overcast day or night).
E - slightly stable conditions.
F - moderately stable conditions.

[b] The degree of cloudiness is defined as that fraction of the sky above the local apparent horizon that is covered by clouds.

Table 2.3. Classification of atmospheric stability by horizontal wind fluctuations[a] (σ_θ), vertical temperature gradient,[b] and Richardson number[c]

Stability classification	Pasquill category	Hor. wind fluctuations, σ_θ, (degrees)	Vert. temp gradient (°C/100 m)	Richardson number
Very (extremely) unstable	A	>22.5	<-1.9	<-1.1
Moderately unstable	B	17.5 to 22.5	-1.9 to -1.7	-1.10 to -0.45
Slightly unstable	C	12.5 to 17.5	-1.7 to -1.5	-0.45 to -0.10
Neutral	D	7.5 to 12.5	-1.5 to -0.5	-0.10 to 0.05
Slightly stable	E	3.8 to 7.5	-0.5 to 1.5	0.05 to 0.10
Moderately stable	F	2.1 to 3.8	1.5 to 4.0	0.10 to 0.15
Very (extremely) stable	G	<2.1	>4.0	

[a]Classification from U.S. Nuclear Regulatory Commission (1972). Horizontal wind fluctuations are the standard deviations of the horizontal wind direction over a period of 15 min to 1 h.
[b]Classification from U.S. Nuclear Regulatory Commission (1972).
[c]Classification by Richardson number from Varma (1982).

3. URANIUM AND FLUORINE MEASUREMENTS

Measurements of uranium and fluorine consisted of air concentrations, particle size distribution information, and deposition data. Table 3.1 gives the locations of samplers for these measurements. As indicated in Table 3.1 (by the letter G), measurements were also made of SF_6 concentrations in the air using an integrated sampler (designated as **gas sampler** in this report and **DIAPEG** in the Geisse report [1989]), but these measurements were not tabulated in the Geisse report. The SF_6 was released with the UF_6 to act as a purely dispersing tracer (no chemical reactions, deposition, or density effects).

3.1 AIR CONCENTRATIONS

Measurements of uranium and fluorine concentrations in the air were made using two types of samplers: (1) integrated or continuous samplers, which were used to determine average concentrations throughout the duration of the release, and (2) sequential samplers, which were used to determine concentrations as a function of time. For the integrated or continuous samplers, uranium and fluorine were collected (1) by bubbling the gas sample through a collecting solution (designated as **bubblers** in this report and **BAPA** in the Geisse report) or (2) by passing the gas sample through a treated filter (designated as **filters** in this report and **DAPAT** in the Geisse report). The sequential samplers (designated as **sequentials** in this report and **VALISES US** in the Geisse report) collected uranium and fluorine by passing sequential gas samples through treated filters. Each sequential sampler took seven sequential gas samples with 3-min durations (numbers 1–7) and one sample (number 0) over the entire test duration. The gas sampling rate was the same for all bubblers (2.78×10^{-5} m^3/s) and for all sequentials (8.33×10^{-5} m^3/s), but each filter had its own rate. These rates ranged from 1.50×10^{-4} to 1.40×10^{-3} m^3/s.

Data from these samplers consisted of the amounts (mg) of uranium and fluorine collected over the sampling period. These data, along with estimates of the precision (mg) of each amount collected, are presented in Tables 1–7 and 10–23 in the Geisse report. In the Geisse report, and independently in this report, these data were converted to normalized concentrations (**C/q** here and **CTA** in the Geisse report), air concentrations, and normalized uranium to fluorine mole ratios (**U/F mole ratio** here and **rapport U/F** in the Geisse report).

The expressions used to convert the amount collected to other quantities are

$$C/q = m/(QF) \quad \text{for } T \geq \tau ,$$

$$= m\,\tau/(QFT) \quad \text{for } T < \tau ,$$

$$q = Q/\tau ,$$

$$C = (C/q)\, q ,$$

$$R_{UF} = (114/238)\, m_U/m_F ,$$

where

C/q = normalized air concentration of either uranium or fluorine, s/m^3,
C = air concentration of either uranium or fluorine, mg/m^3,
q = release rate of either uranium or fluorine, mg/s,
m = amount of either uranium (m_U) or fluorine (m_F) collected, mg,
Q = amount of uranium (4.9426×10^{7g} mg) or fluorine (2.3674×10^7 mg) released over the duration of the test, mg,
F = gas sampling rate, m^3/s,
T = duration of sample collection, s
τ = duration of test, 900 s,
R_{UF} = normalized uranium to fluorine mole ratio (U/F mole ratio).

Numbers 1–7 of the sequentials were collected over 3-min durations (T = 180 s); the other samples were collected over 15-min (or longer) durations. The values of normalized concentrations and normalized uranium to fluorine ratios derived from the air concentration measurements are presented in Tables 33–53 in the Geisse report. The concentrations are presented in Tables 60–80.

As indicated in Table 3.1, no data were reported for 7 of the 65 filter samplers. Also, there is some uncertainty about the locations of the filters at a distance of 40 m and a height of 2 m. Plate 1 and Table 8 in the Geisse report indicate the filters are at azimuths 300°, 312°, and 324° while Tables 12, 42, 69, and 90 indicate the filters are at azimuths 300° and 354°. This report assumes that 354° is a typographic error and the correct locations are 300° and 324° (no data were reported for 312°). These locations are closer to being symmetrical about the 315° azimuth, and the other samplers seem to have this same approximate symmetry.

Values of C/q, R_{UF}, and C were recalculated in this report (see Appendices A, B, and C) by using the values for the amounts of uranium and fluorine collected which are given in Tables 1–7 and 10–23 in the Geisse report. In making these calculations, a number of inconsistencies were discovered in the tables in the Geisse report. The estimates of precision for the amount of uranium collected in Tables 1–7 (bubblers) did not follow the estimating rules given in the table labeled "32 bis." However, the estimates of precision in all of the derived values for uranium (CTA, Rapport U/F, and concentration) were all consistent with these estimating rules. The uranium precision values in Tables 1–7 are repeated in Appendix A in this report but were not used in the recalculations. Also, the CTA, Rapport U/F, and concentration values for both uranium and fluorine that were derived from the amounts collected by the sequentials (Tables 17–23 in the Geisse report) were not consistent unless the amounts collected were divided by a factor of 1.1. The reason for this factor is not given in the Geisse report nor is it obvious from the information provided. However, in order to remain consistent with the derived values in the Geisse report, this factor was used to derive the C/q and C values given in Appendix C in this report. Finally, many of the values calculated in this report did not equal the corresponding values in the Geisse report. These discrepancies are believed to be due to arithmetic and typographic errors in the Geisse report. The values in the appendices are "shaded" to indicate where these discrepancies occurred.

Table 3.1. Layout of sampling grid

(See page 10 for explanation of table.)

Number			2	3	4		5	6	7	8		9	10	11	12		13	14	15	16
Angle		360	354	348	342	337.	336	330	324	318	315	312	306	300	294	292.5	288	282	276	270
Dis	Ht	Sampling devices																		
10	0	d	D	D	D		D	D	D	D		D	D	D	D		D	D	D	D
10	1		B	B	B		B	B	B	B		B	B	B	B		B	B	B	B
10	2							B		BIP		B	B		B					
20	0	D	D	D	D		D	DB	DB	DB		DB	DB	DB	DB		DB	D	D	D
20	1	B	f	F	B	S	B	B	B	BIP	S	B	B	B	B	S	B	B	F	B
20	2							B	B	B		B	B	B	B		B			
20	3					S					S					S				
20	6					S					S					S				
40	0	D	D	D	D		DB	Q	QB	Q		QB	Q	QB	Q		QB	Q	Q	D
40	1	FG	FG	FG	FG	S	FG	FG	FG	FGI	S	FG	FG	fG	FG	S	fG	FG	FG	FG
40	2								F			f		F						
40	3					S					S					S				
40	8					S					S					S				
40	15										S									
70	0	d	Q	Q	Q		Q	Q	QB	Q		QB	D	DB	D		D	D	D	d
70	1		FG	F	FG		FG	FG	FG	FG	IP	FG	FG	FG	fG		FG	F	FG	
70	2								F			F		F						
100	0	d	d	D	D		D	Q	Q	Q		Q	Q	Q	Q		Q	Q	d	d
100	1		FG	F	FG		FG	FG	fG	FG	IP	FG	FG	FG	FG		FG	F	FG	
200	0	d	d	d	d		D	Q	Q	Q		Q	Q	Q	Q		Q	d	d	d
200	1		FG		fG		FG	FG	FG	FG		FG	FG	FG	FG		FG		FG	

EXPLANATION OF SAMPLING GRID

Number is the nominal designation of the azimuthal position.
Angle is the azimuthal position, in degrees, at a given radial distance.
Dis is the radial distance (in meters) on the sampling grid.
Ht is the height (in meters) above ground level in meters.
Type of Sampler

- D is a petri dish for integrated deposition sampling.
- d is a petri dish but no data were reported.
- Q is a petri dish but results are questionable because sand was found in the sample.
- B is a bubbler for integrated sampling of U and F.
- F is a filter sampler for integrated sampling of U and F.
- f is a filter sampler but no data were reported.
- S is a sequential sampler (provided by VALISES US) for U and F.
- G is a gas sampler for SF_6 but no data were reported.
- I is an Andersen Impact sampler for particle size distribution.
- P is a Scotch paper collector for integrated deposition sampling.

3.2 PARTICLE SIZE DISTRIBUTION MEASUREMENTS

Particle size distribution measurements were made at the five locations listed in Table 3.1 using Andersen Impact samplers. Uranium and fluorine were collected in each of nine particle size ranges, which are given in microns (μm) below:

0 to 0.4
0.4 to 0.7
0.7 to 1.1
1.1 to 2.1
2.1 to 3.3
3.3 to 4.7
4.7 to 5.8
5.8 to 9.0
>9.0

These data are given in Table 25 in the Geisse report and Appendix D of this document. Values of R_{UF} were calculated for these data in this report and are also given in Appendix D.

3.3 DEPOSITION MEASUREMENTS

Deposition measurements were made at the locations indicated in Table 3.1 using Scotch paper collectors (uranium only) and petri dishes (uranium and fluorine). These included the

This information was used to calculate areal depositions (mg/m^2) and, in conjunction with the concentration measurements, was used to estimate uranium and fluorine deposition velocities. Values of R_{UF} were also calculated using the information from the petri dishes. Data on the amounts collected are given in Tables 26–32, values of areal depositions and deposition velocities are given in Tables 54–59, and R_{UF} values are given in Tables 59-1 through 59-6 in the Geisse report. Table D.4 in Appendix D (this report) provides the corresponding information for the Scotch paper collectors and Appendix E provides this information for the petri dishes. The deposition velocities for petri dishes are derived from C/q values determined from either bubblers or filters located at a height of 1 m above the dishes. For Scotch paper collectors, the nearest concentration measurement was used.

The expressions used to convert the amount deposited to areal depositions and deposition velocities are

$$D = m/A ,$$

$$V = D/[(C/q)\ Q] ,$$

where

D = areal deposition of either uranium or fluorine on the ground, mg/m^2,
A = collecting area of the sampler for ground deposition, 0.25 m^2 for the Scotch paper collectors and 0.0147 m^2 for the petri dishes,
V = deposition velocity for either uranium or fluorine, m/s.

As indicated in Table 3.1, results for several of the petri dishes are questionable because sand was found in the samples. These samples are indicated by a footnote in Appendix E. Also, like some of the concentration-related results, many of the calculated values in this report did not agree with the corresponding values in the Geisse report and these values are "shaded" to indicate where the discrepancies occurred.

4. OTHER MEASUREMENTS

4.1 VIDEOTAPE

Two video cameras recorded the plume trajectory during the test. One camera was located 20 m directly behind (upwind) the release point at an elevation of 5 m. Although this camera provided views of the initial horizontal growth of the plume, quantitative data could not be obtained from the images from this camera because the observed plume width could not be related to the downwind distance. The second camera was located downwind and off to the side of the plume trajectory. Images from this camera could be used to estimate the vertical dimensions of the plume as a function of downwind distance if the exact location of this camera were known with respect to landmarks (sampling towers) visible in the pictures. These vertical dimensions of the plume could then be used to estimate vertical dispersion coefficients. However, the exact location of this camera was not given and it would be very difficult and inaccurate to do this analysis without this information. Consequently, no estimates of vertical dispersion coefficients were made.

4.2 TEMPERATURE MEASUREMENTS

Temperatures within the plume were measured with thermocouples placed on three grids located at distances of 1, 2, and 4 m downwind of the release point. The grid at 1 m downwind had 11 thermocouples while the others contained 17. However, data were reported only for the center thermocouple for the 2- and 4-m grids. The center of each grid was at the 315° azimuth and 3.15 m above the ground. Thermocouples were located at the center of each grid and at horizontal and vertical distances of 25 cm. The grid at 1 m downwind had five thermocouples in the center row and three in the row above and below to make up the total of eleven. The grids at 2 and 4 m downwind had five in each of these three rows plus one each at the center (315° azimuth) above and below these rows. The data were provided as plots of temperature versus time at each location. These plots and figures showing the arrangement of the thermocouples are given in Appendix F.

The temperature plots showed rapid fluctuations which were probably due to intense turbulence generated by the chemical reactions close to the release point. Because of these fluctuations, it has not yet been decided how best to analyze these data; consequently, no analyses of the temperature data are given in this report.

5. ANALYSIS OF DATA

The derived data (C/q, R_{UF}, and D) were plotted, and interpretations were made on the basis of these plots. In addition, runs were made with the Energy Systems UF_6 dispersion model to simulate the experimental C/q values to assess the validity of the model.

5.1 C/q AS A FUNCTION OF DOWNWIND DISTANCE AND AZIMUTH

Figures 5.1–5.5 show the experimental values of C/q over the entire duration of the release as a function of azimuth. These are the individual points on the graphs and include the values from the bubblers, filters, and sequence 0 of the sequentials. The curves on these graphs are the results of the simulations using the Energy Systems UF_6 dispersion model.

The model simulation was based on the actual release conditions (81.2 g UF_6/s directed upward from a 0.05-m-diam pipe at a height of 3.15 m) and an assumed atmospheric stability of Class B. Simulations were conducted for all stability classes, and Class B provided the best fit between the model and the data for regions near the centerline of the plume. As indicated in Sect. 2.2, two of the four criteria for evaluating stability indicated Class B.

The simulations were done for heights of 0, 1, 2, 3, 6, 8, and/or 15 m to correspond to the heights where data were taken. In Figs. 5.1–5.4 (10 to 70 m downwind), the simulated results for uranium and fluorine coincide so there is a single curve for each height. The curves for heights of 0, 1, 2, (and 3) m are easily distinguishable at 10 m downwind (Fig. 5.1) but come together at greater downwind distances. There is no room in Fig. 5.2 (20 m downwind) to designate the curve for the 2-m height, which falls between the 1- and 3-m curves. Similarly, the 0- and 1-m curves practically coincide in Fig. 5.3 (40 m downwind), and there is no room to designate the curve for the 2-m height, which falls between the 0- and 3-m curves. In Fig. 5.4 (70 m downwind), the 0- and 1-m curves coincide and the curve for the 2-m height falls slightly below the 0- and 1-m curves. At 100 and 200 m downwind (Fig. 5.5), the curves for 0, 1, 2, and 3 m coincide, but there is now a distinguishable difference between the uranium and fluorine curves. There is no room in Fig. 5.5 to designate the fluorine curve for 100 m downwind, which falls just below the corresponding uranium curve.

If fluorine and uranium disperse in an identical manner, the values of C/q for both elements at the same location would be identical. Figures 5.1–5.5 show most of the fluorine and uranium points to be very close to each other, but a small difference can be detected with some. These figures and the results tabulated in Appendices A, B, and C generally indicate uranium values are slightly below the fluorine, but the opposite situation sometimes occurs. However, the simulated uranium values are always slightly larger than the fluorine values.

For the dispersion to be identical, either both species are depleted at the same rate from the plume or depletion rates are negligible. Depletion rates are proportional to the deposition velocities tabulated in Appendices D and E. These values are very small, ranging from about 9×10^{-5} to 0.02 m/s (average is 6.3×10^{-4} m/s) for uranium and 6×10^{-5} to 5×10^{-3} m/s (average is 6.6×10^{-4} m/s) for fluorine. Deposition velocities for fluorine generally are smaller than the values for uranium, and this is consistent with the observed

C/q values for fluorine generally being greater. Deposition velocities derived from the 1987 test (Just and Bloom, 1989, pp. 45 and 46) were smaller, ranging from about 7×10^{-6} to 6×10^{-4} m/s for uranium (average was 2.3×10^{-4} m/s) and 2×10^{-5} to 4×10^{-4} m/s for fluorine (average was 1×10^{-4} m/s).

The simulation used the default deposition velocities built into the model (other values could have been entered as input), which were 4.97×10^{-4} m/s for UO_2F_2 and 7.69×10^{-2} m/s for HF. These are equivalent to 4.97×10^{-4} m/s for uranium and 5.14×10^{-2} m/s for fluorine. The higher deposition velocity for HF explains why simulated C/q values for fluorine are below corresponding values for uranium. The higher deposition velocity for HF is based on the assumption that it would react with materials on the ground and thus create a greater driving force for plume depletion as compared with the uranium. The experimental results seem to imply that the HF is not in a very reactive form or the driving force is not enhanced by the reactions. However, both deposition velocities are so small that even a 100-fold difference results in only slight differences in the simulated C/q values for uranium and fluorine.

The highest C/q values at a given downwind distance will occur at the plume centerline. The elevation of the simulated plume centerline started at 3.15 m at the release point, rose to 3.69 m at about 0.8 m downwind, fell to 3.25 m at about 9.7 m downwind, and rose to level-off at 3.32 m at about 30 m downwind. Since the elevation of the plume centerline seemed to remain at about 3 m, it is reasonable to expect that C/q values at the 2- and 3-m elevations will be greater than the values at 0, 1, 6, 8, and 15 m. This expectation appears to be valid for the experimental data at the downwind distances of 10, 20, 40, and 70 m (Figs. 5.1–5.4) where measurements were made as a function of height. There is not much variation with height for the data at elevations of 0, 1, 2, and 3 m, but the variation is very evident at elevations of 6, 8, and 15 m. The model results show a more pronounced variation with height than the data at the lower elevations and a much weaker variation than the data at the higher elevations. Both the data and the model results show the values for elevations of 0, 1, 2, and 3 m tend to merge with increasing downwind distance.

Simulated results are in reasonable agreement with the experimental data for heights of 0 to 3 m near the centerline of the plume. However, experimental values of C/q are consistently higher than simulated values at azimuths far from the centerline. Conversely, experimental values are consistently lower at heights above 3 m. A similar effect with azimuths can be observed in the paper by B. Crabol et al. (1991) which compared these data with a Gaussian model developed by A. Doury (1976). The horizontal and vertical dispersion coefficients in the Doury model and the default values in the Energy Systems model (other values can be entered as input) are similar to the Pasquill-Gifford values (Gifford, 1976). However, the Pasquill-Gifford dispersion coefficients were derived mostly from data on elevated releases and do not apply very well to ground-hovering plumes. Since the height of the plume centerline seemed to remain at about 3 m at all downwind locations, the UF_6 release essentially behaved as a ground-hovering plume. The experimental variation of C/q with azimuth indicates that simulated horizontal dispersion coefficients are too small, while the vertical variation indicates that simulated vertical dispersion coefficients are too large. This is a characteristic fault with models that depend on the Pasquill-Gifford dispersion coefficients when they are applied to ground-hovering plumes. A key feature of dense gas models is an attempt to properly account for these differences in dispersion characteristics.

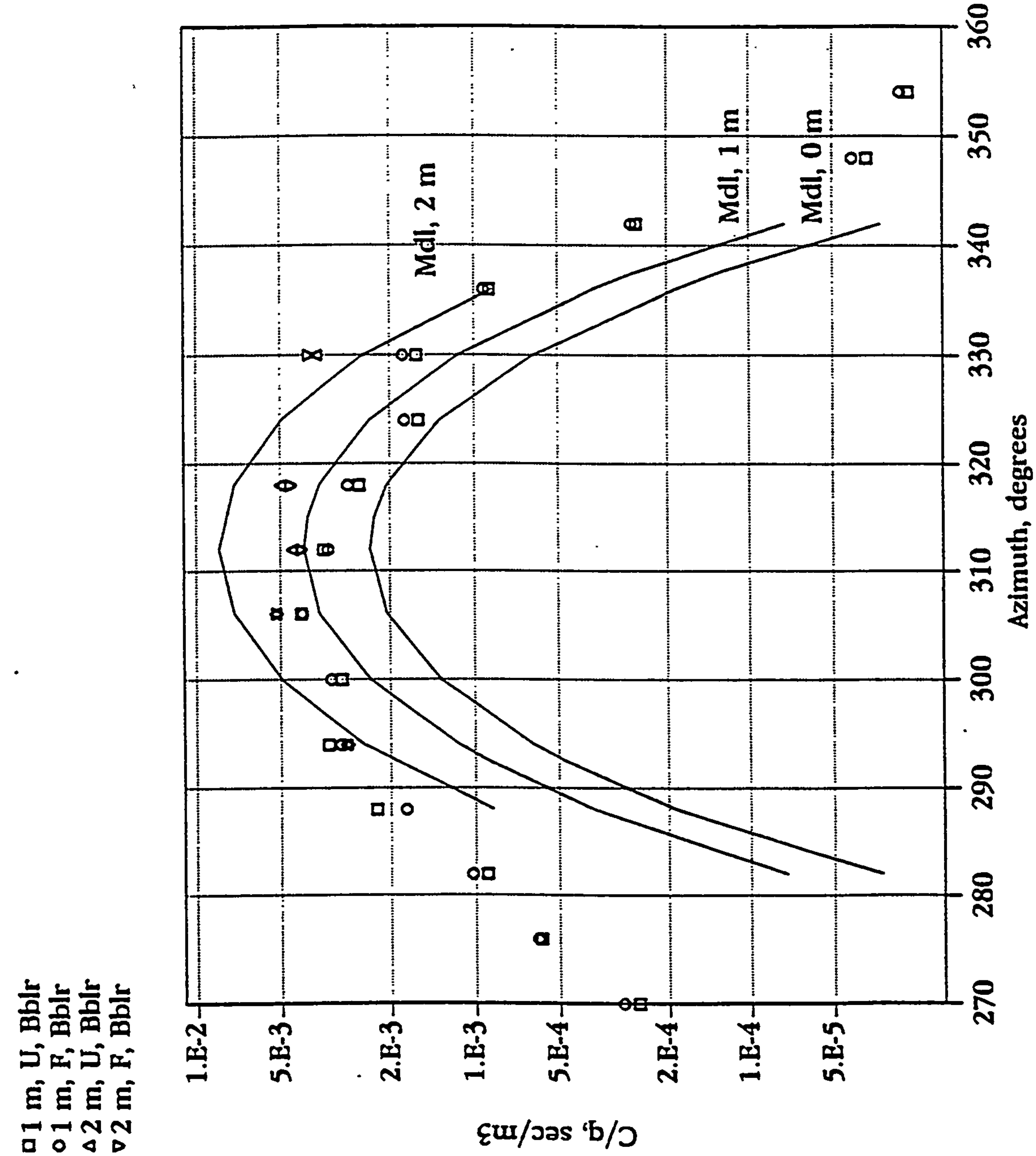

Fig. 5.1. C/q versus azimuth at 10 m downwind.

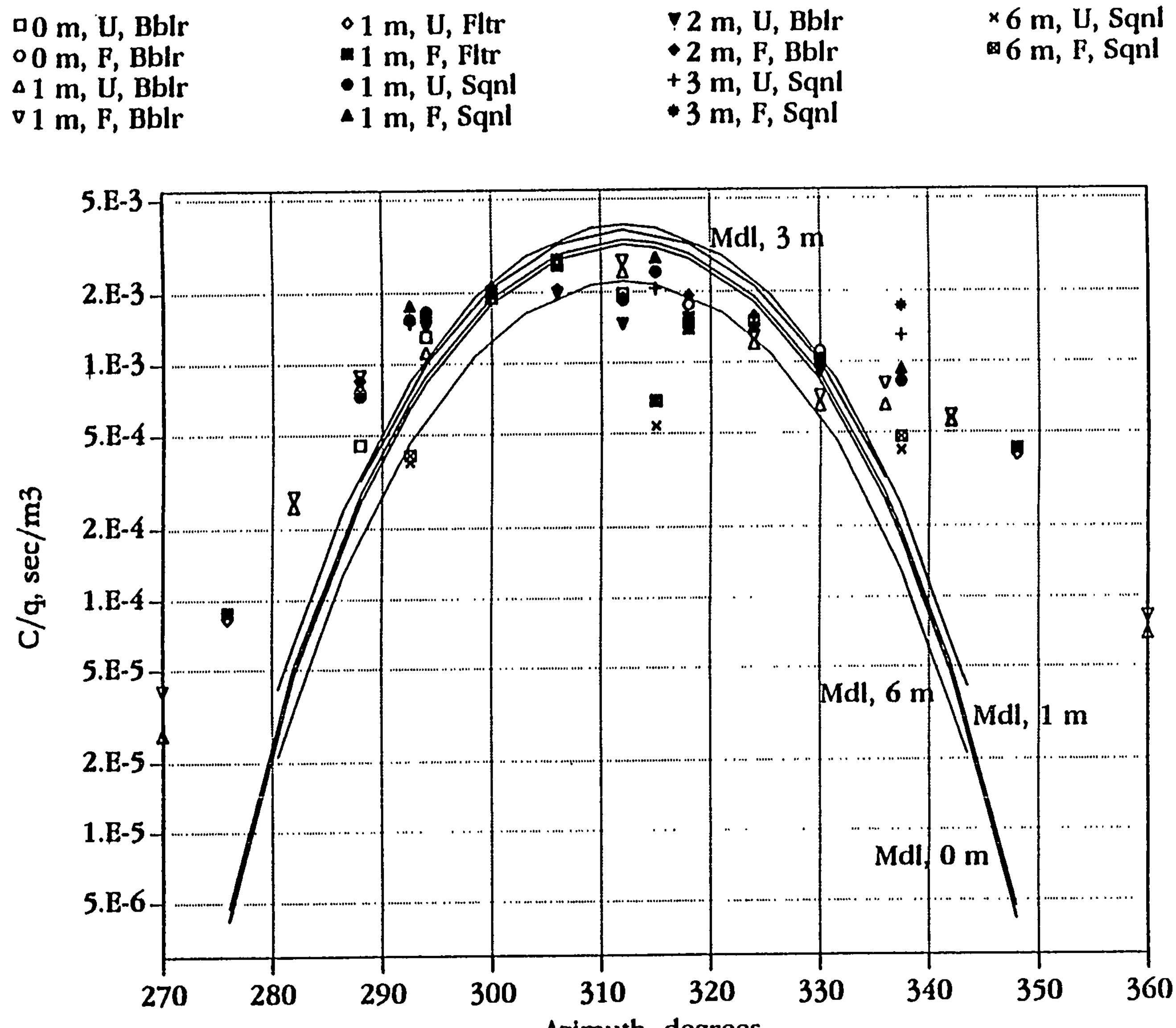

Fig. 5.2. C/q versus azimuth at 20 m downwind.

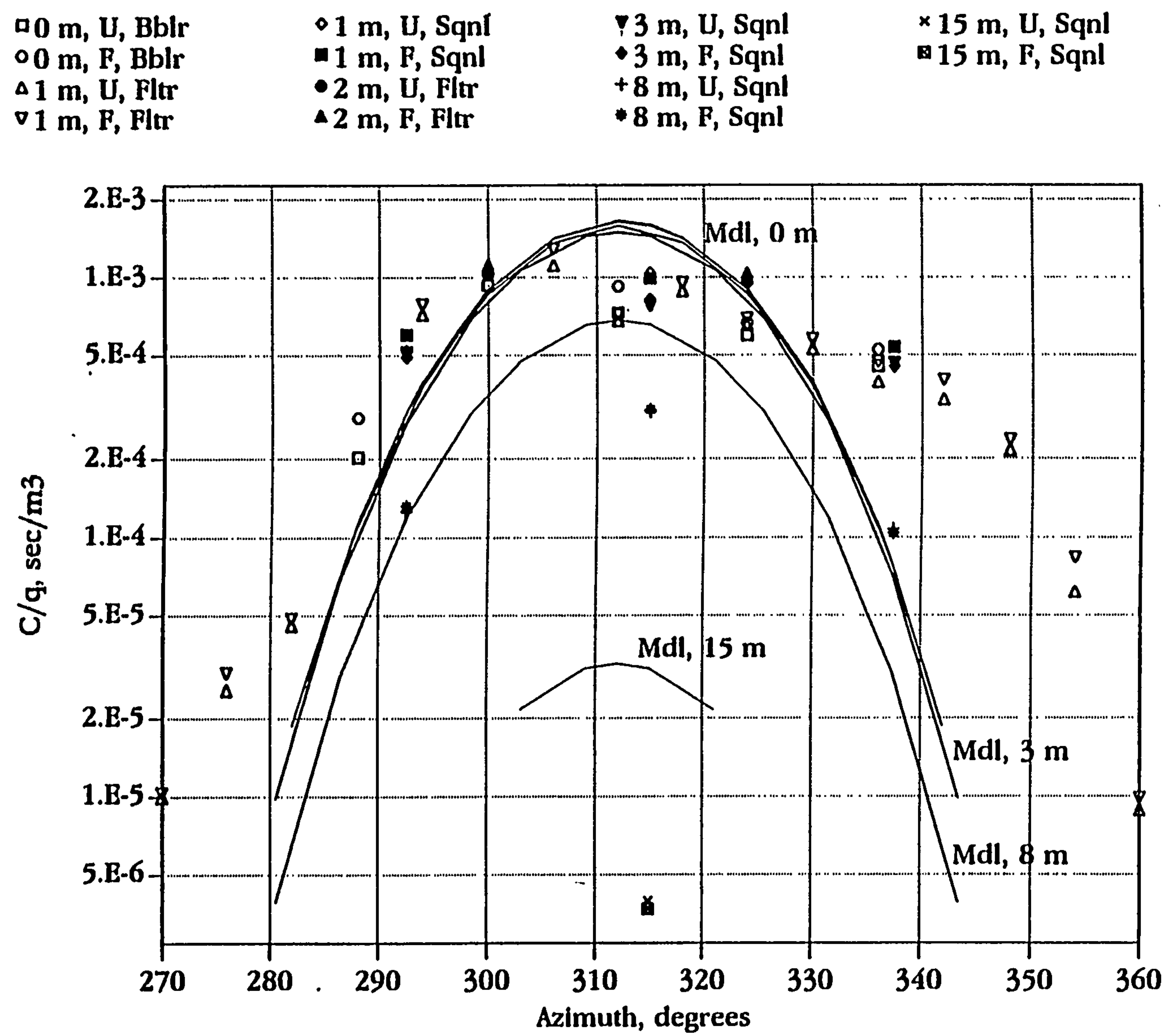

Fig. 5.3. C/q versus azimuth at 40 m downwind.

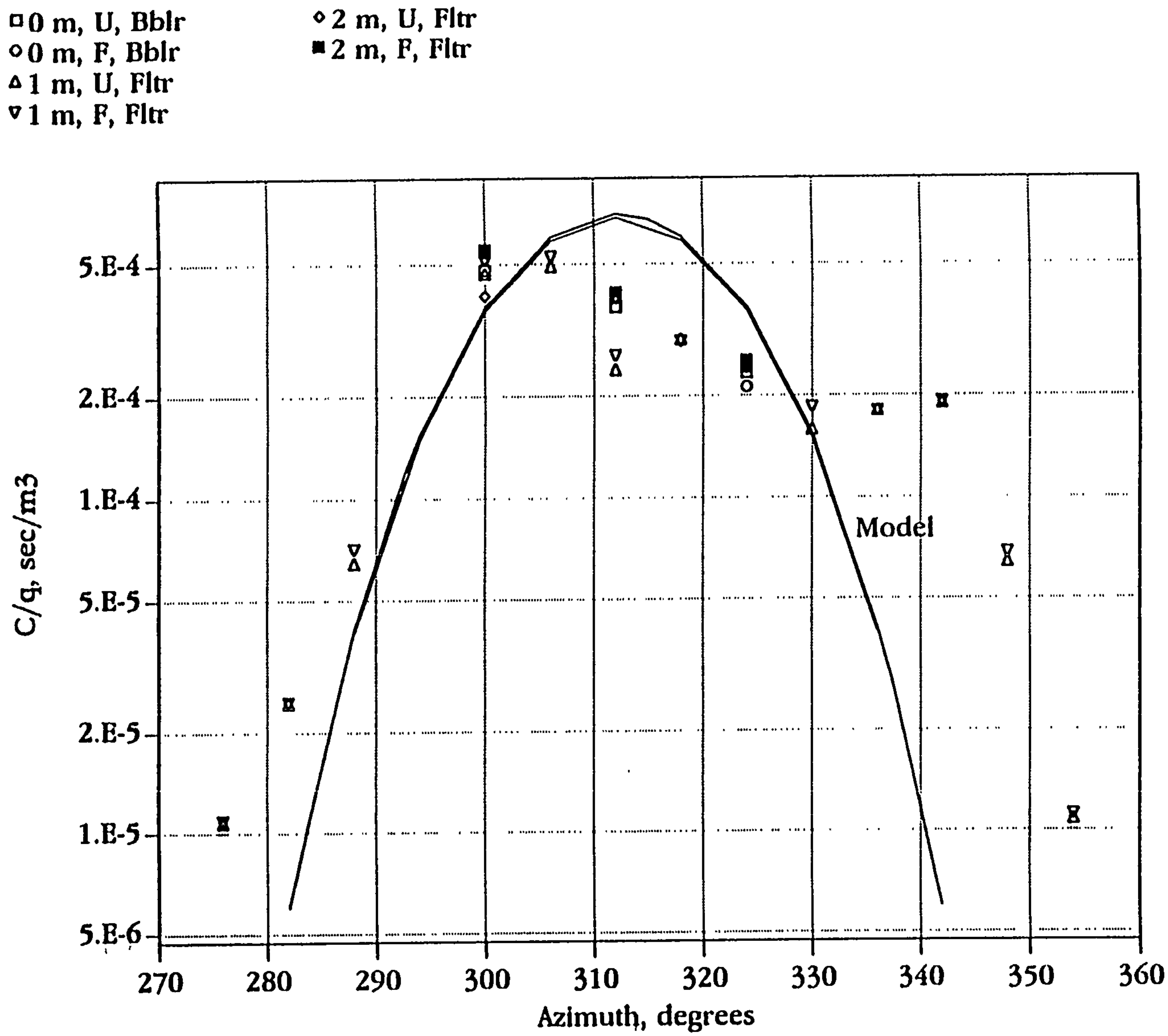

Fig. 5.4. C/q versus azimuth at 70 m downwind.

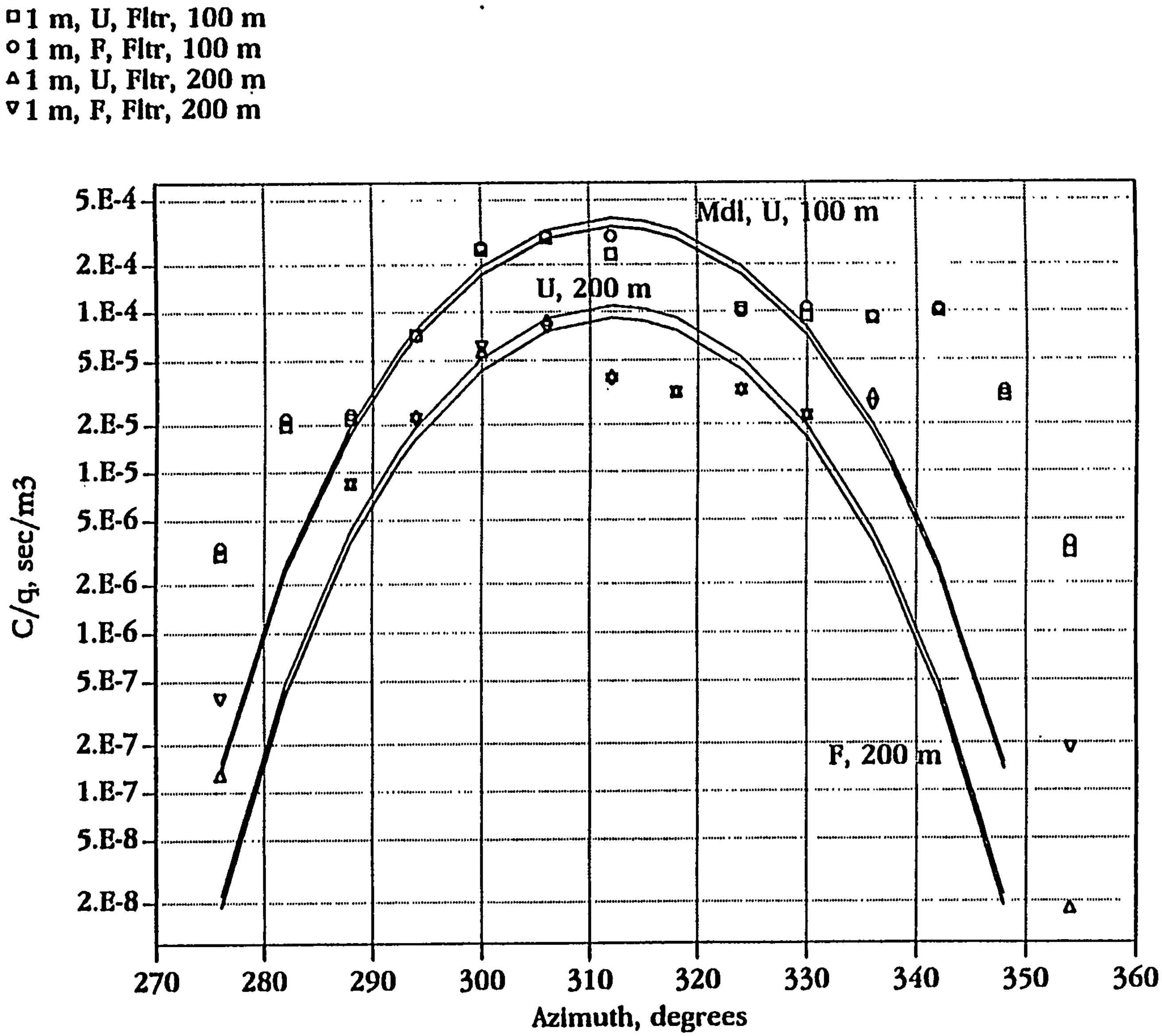

Fig. 5.5. C/q versus azimuth at 100 m and 200 m downwind.

The Energy Systems model can input several parameters, particularly dispersion coefficients and deposition velocities, which may make the computed results agree much closer with the experimental data; however, inputing such parameters was not considered a fair test of the model. Unless methods are available to estimate these parameters prior to the release test, only the default values in the model would be available in any real situation.

Based on the comparisons between the simulated results and experimental data shown in Figs. 5.1–5.5, it is recommended that the Energy Systems model can be used, with some modification, to simulate relatively dilute releases of gaseous UF_6. However, the deposition velocity for fluorine should be reduced to a value (e.g.,1×10^{-4} m/s) slightly smaller than that for uranium. Such a value would be consistent with the particle sizes measured in these tests. For concentrated releases of gaseous UF_6, the dispersion coefficients would have to be modified to better simulate ground-hovering plumes.

The data in Figs. 5.1–5.5 imply that the mean wind direction during the release was about 306° rather than 316° as indicated in Table 2.1. However, there is too much scatter in the data to be certain. The simulations assumed the direction was 312°, and these results are within the scatter of the data in the 300° to 330° interval. The variations in the wind direction were within this interval during the test (Fig. 2.1).

As indicated in Table 3.1, no location contained more than one sampling device to measure the air concentration of uranium or fluorine. Consequently, it was not possible to directly compare the results using different sampling devices for this test. However, direct comparisons between bubblers and filters were made at eight locations during the April 10, 1987, UF_6 release test (Just and Bloom, 1989, pp. 21 and 22), and these comparisons indicated a range of 0.480 to 1.304 in the ratio of the bubbler to filter results. The trends of the data for the June 5, 1989, test at downwind distances of 20, 40, and 70 m (Figs. 5.2–5.4), indicate the results from different samplers are probably in this same range.

5.2 C/q AND U/F MOLE RATIO AS FUNCTIONS OF TIME

Values of C/q and the U/F mole ratio, derived from sequences 1–7 of the sequentials, are shown as a function of time in Figs. 5.6–5.24. Each sequence number represents the end of a 3-min interval such that sequence 1 sampled from the start of the test to 3 min into the test, while sequence 7 sampled from 18 to 21 min into the test. Figures 5.6–5.24 also include the overall values based on samples taken over the entire 21-min sampling period (sequence 0).

The samplers were located 20 and 40 m downwind from the release point at azimuths of 292.5°, 315°, and 337.5° (Table 3.1). With a wind speed of 3.7 m/s or greater (Table 2.1), the travel time to the samplers (less than 11 s) was negligible compared with the sampling intervals. Consequently, the variations of C/q with time should be expected to correlate with the wind direction in Table 2.1 and Fig. 2.1. The 2-min average wind direction during the release (17:32 to 17:46 in Table 2.1) ranged from 304° to 322° at the 10- and 28-m elevations. The wind direction was more towards the 337.5° samplers during sequences 1, 2, and 5 (3, 6, and 15 min into the test) and towards the 292.5° samplers during sequence 3 (9 min into the test). Figures 5.19–5.24 seem to show the corresponding peak in C/q for the 292.5° samplers during sequence 3. Also, Figs. 5.6–5.11 seem to show the corresponding peaks in C/q for the 337.5° samplers during sequences 1, 2, and 5, except the data at 20 m downwind and 6 m high (Fig. 5.10). The data in Fig. 5.10 shows a peak at sequence 2 and resembles the trend of the data for the 315° samplers. The C/q data for the 315° samplers (Figs. 5.12–5.18) do not seem to show consistent peaks but show relatively constant values for sequences 2–5 and low values for sequences 1, 6, and 7. Since the wind direction during the release ranged from 304° to 322°, the relatively constant values for sequences 2–5 are expected, but the low value for sequence 1 is difficult to explain. Low values for sequences 6 and 7 appear in the data for all three azimuths and is probably due to the termination of the release (at the end of sequence 5). The exception is the data for the 15-m height (Fig. 5.18), which cannot be explained.

The U/F mole ratio (R_{UF}) can range from zero (for HF only), through 1.0 (for UO_2F_2 associated with 4HF), to 3.0 (for UO_2F_2 only). The C/q data seem to indicate that the HF and UO_2F_2 disperse in a similar manner except for small differences due to deposition. Consequently, the expected average value for R_{UF} should be slightly less than 1.0 since the experimental deposition velocity for uranium generally is greater than that for fluorine. R_{UF} values based on data taken from bubblers, filters, and sequence 0 of the sequentials (shown in Sect. 5.3) generally show values slightly less than 1.0. However, the trends of the R_{UF} values based on sequences 1–7 of the sequentials seem to follow the trends of the C/q data. The discussion of the particle-size data (Sect. 5.6) implies the particles are primarily UO_2F_2 (R_{UF} = 3.0) rather than UO_2F_2 associated with 4HF (R_{UF} = 1.0). Therefore, the higher R_{UF} values in Figs. 5.6–5.24 seem to indicate a higher percentage of particles than the lower R_{UF} values. It seems reasonable that the particles would tend to move directly with the wind and appear in smaller amounts off the main wind direction. Consequently, the R_{UF} values would tend to show peak values at about the same time as the C/q peak values.

Some of the R_{UF} values may be indications of errors, and R_{UF} values much greater than 3.0 (Fig. 5.20) are definite indications of errors. Another indication of error in the sequentials is the unexplained factor of 1.1 mentioned in the last paragraph of Sect. 3.1. A third indication of error is that the sum of the weights collected in sequences 1–7 were always less than the weights collected in sequence 0 (Appendix C). Just (1986, pp. 48–52) and Just and Bloom (1989, pp. 31–38) also found similar discrepancies in the previous tests. However, the discrepancies in earlier tests were smaller and were random (the sum of the weights collected in sequences 1–7 were sometimes greater than sequence 0).

5.3 R_{UF} AS A FUNCTION OF DOWNWIND DISTANCE AND AZIMUTH

Figures 5.25–5.29 show the experimental values of the U/F mole ratio (R_{UF}) over the entire duration of the release as a function of azimuth. The data from the gas samplers (bubblers, filters, and sequence 0 of the sequentials) are shown as individual points while the petri dish data are connected with lines.

Because the C/q data seem to indicate that HF and UO_2F_2 disperse in a similar manner and the experimental deposition velocity for uranium is greater than that for fluorine, the expected average value of R_{UF} based on gas samplers should be slightly less than 1.0. Data from the gas samplers (bubblers, filters, and sequence 0 of the sequentials) show values ranging from about 0.6 to about 1.2 (average is 0.92) with most of the values between 0.8 and 1.0.

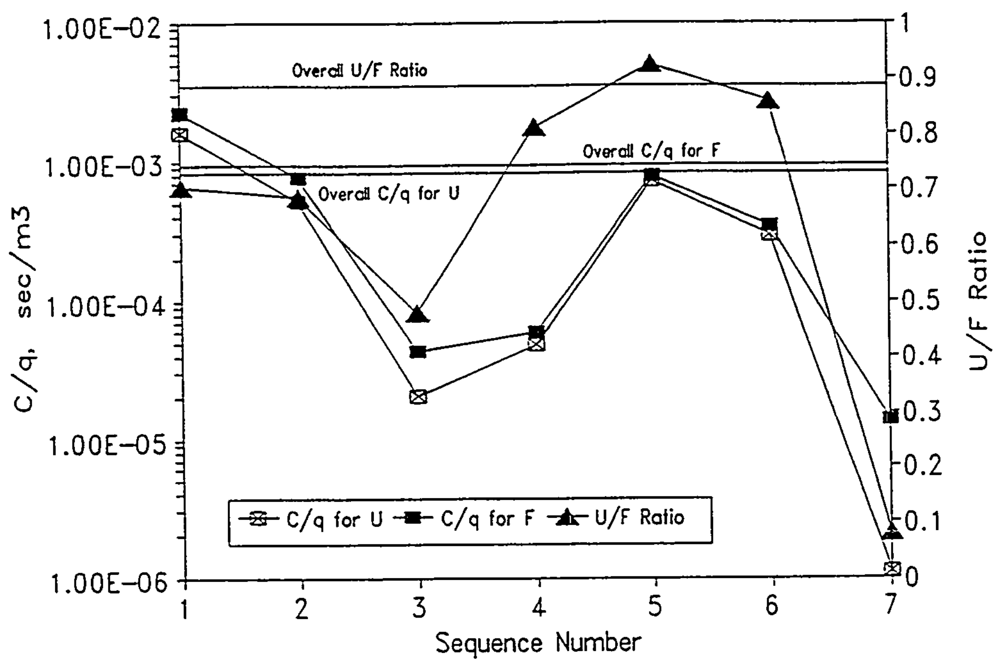

Fig. 5.6. C/q and U/F ratio versus sequence number at 20 m downwind, 1 m high, and 337.5° azimuth.

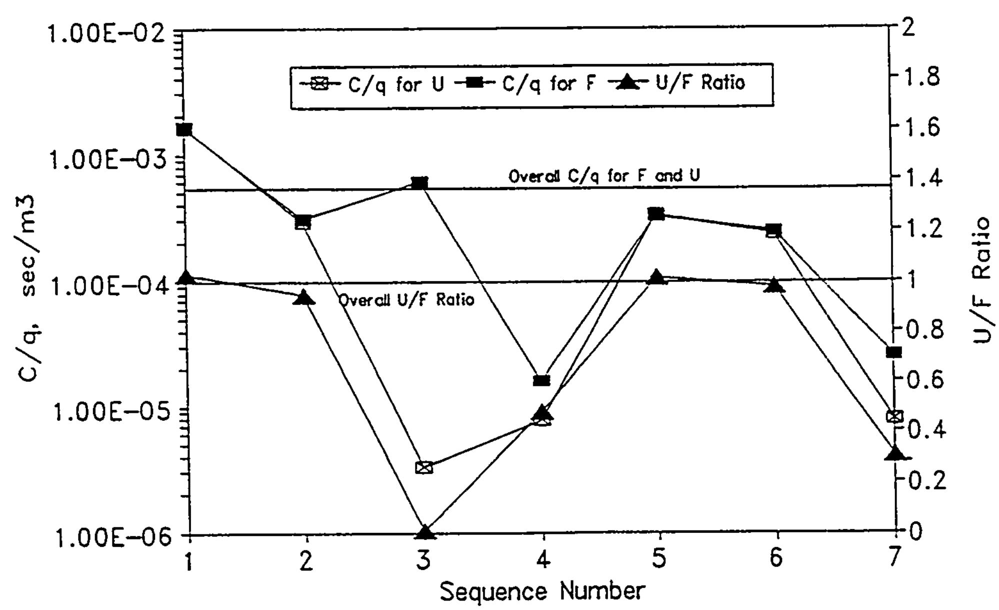

Fig. 5.7. C/q and U/F ratio versus sequence number at 40 m downwind, 1 m high, and 337.5° azimuth.

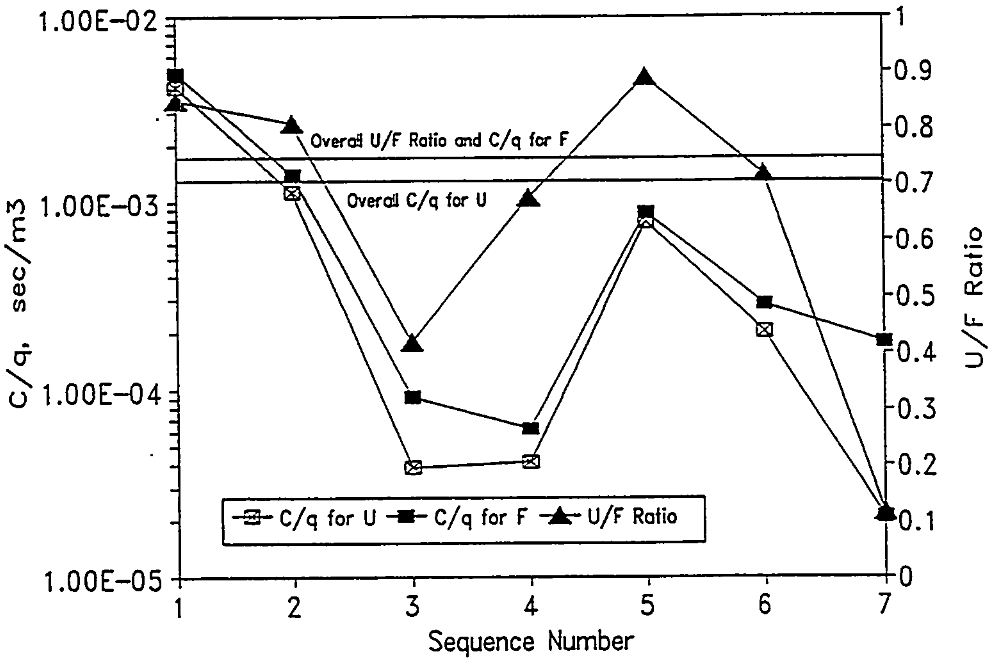

Fig. 5.8. C/q and U/F ratio versus sequence number at 20 m downwind, 3 m high, and 337.5° azimuth.

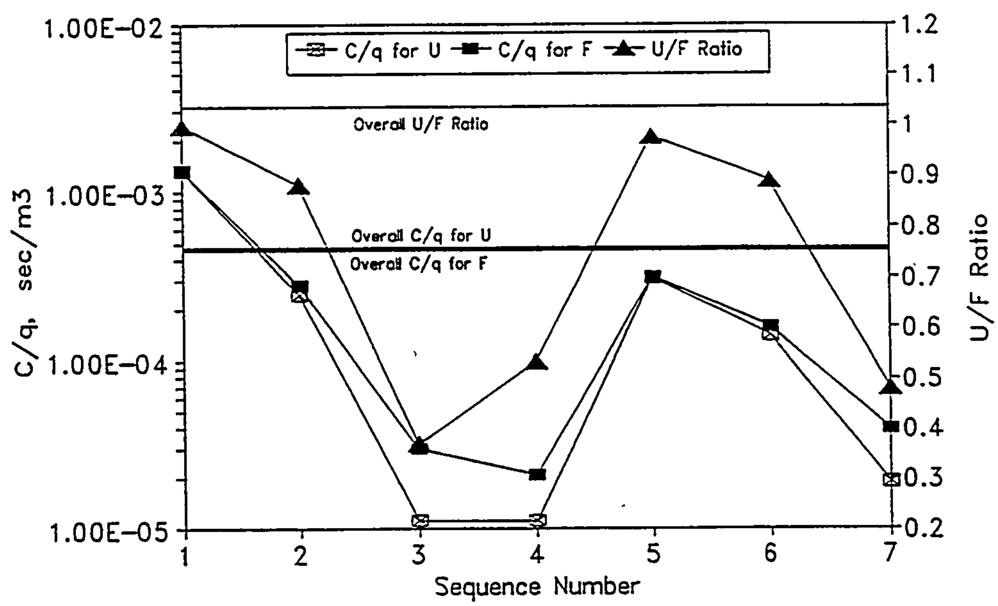

Fig. 5.9. C/q and U/F ratio versus sequence number at 40 m downwind, 3 m high, and 337.5° azimuth.

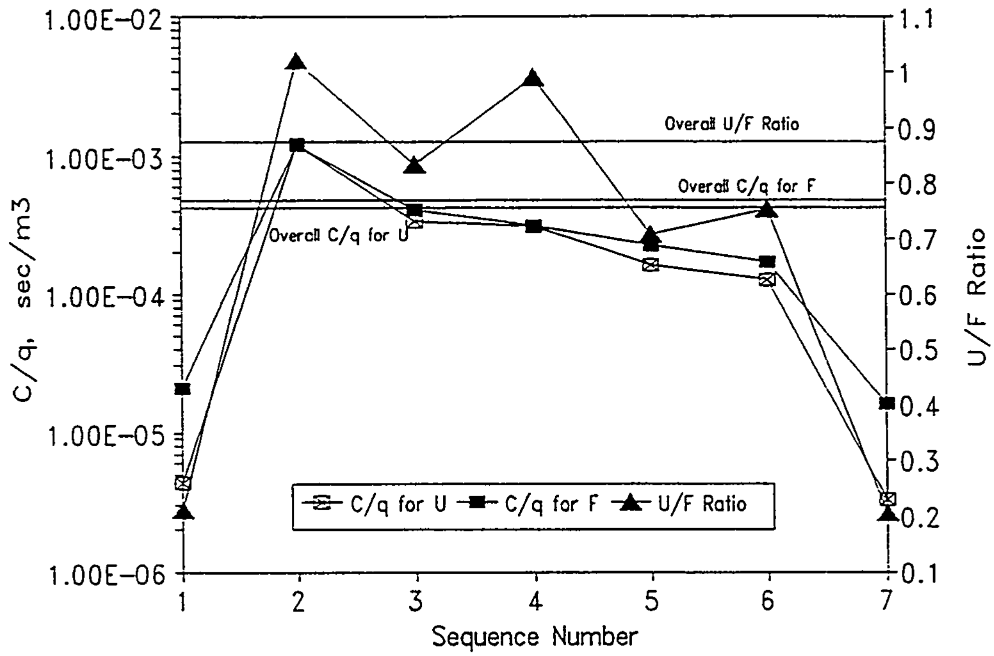

Fig. 5.10. C/q and U/F ratio versus sequence number at 20 m downwind, 6 m high, and 337.5° azimuth.

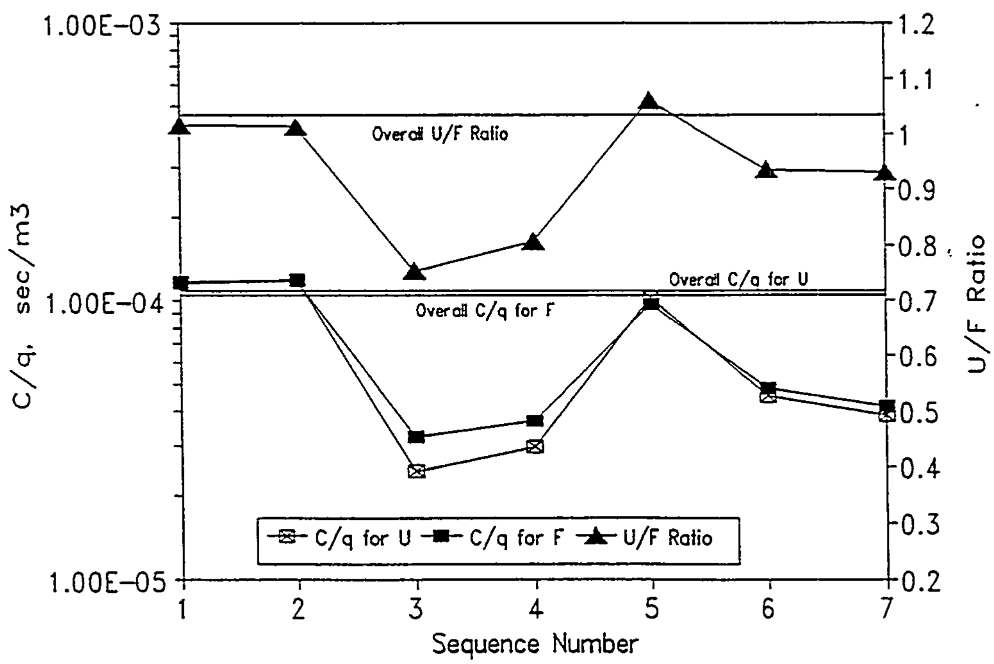

Fig. 5.11. C/q and U/F ratio versus sequence number at 40 m downwind, 8 m high, and 337.5° azimuth.

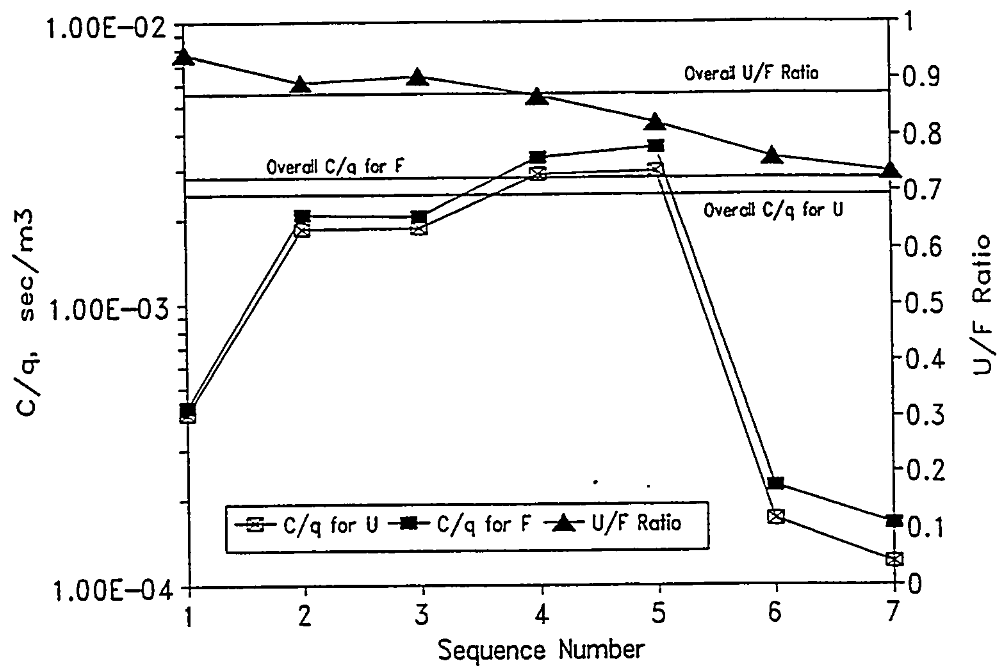

Fig. 5.12. C/q and U/F ratio versus sequence number at 20 m downwind, 1 m high, and 315° azimuth.

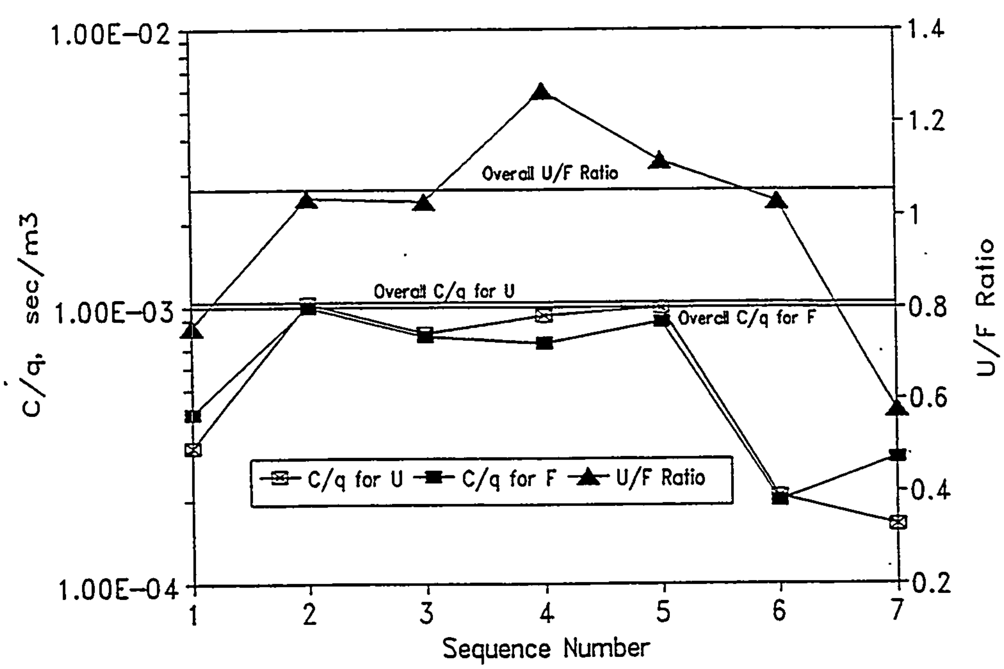

Fig. 5.13. C/q and U/F ratio versus sequence number at 40 m downwind, 1 m high, and 315° azimuth.

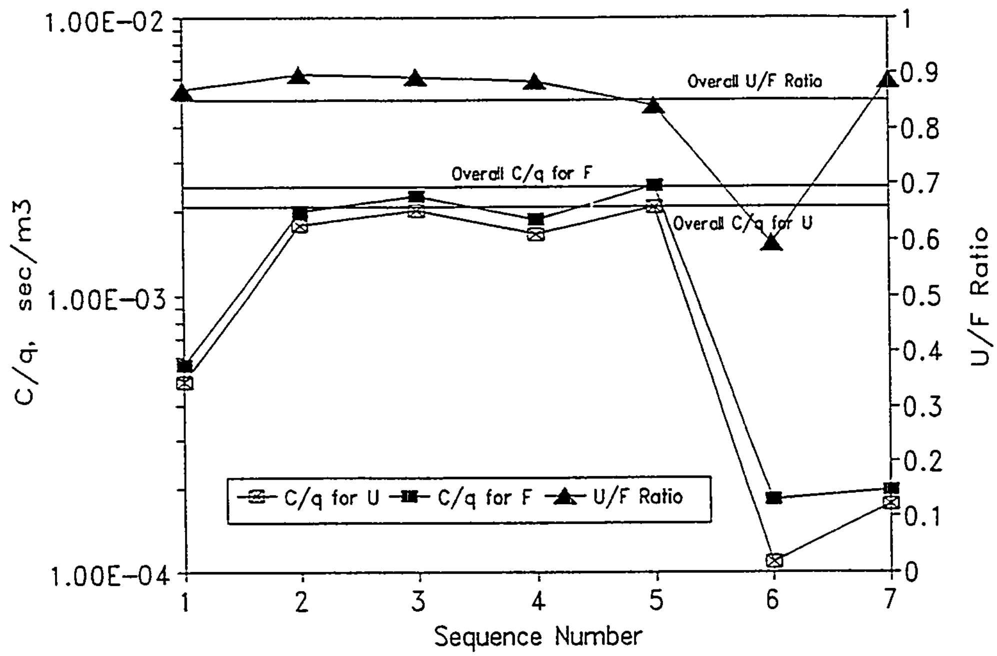

Fig. 5.14. C/q and U/F ratio versus sequence number at 20 m downwind, 3 m high, and 315° azimuth.

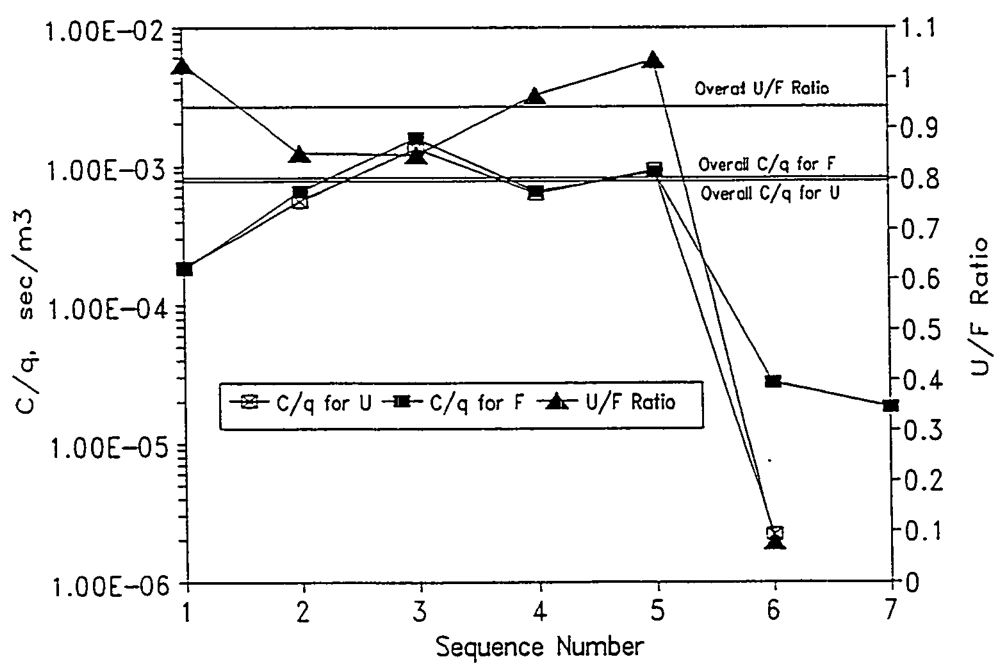

Fig. 5.15. C/q and U/F ratio versus sequence number at 40 m downwind, 3 m high, and 315° azimuth.

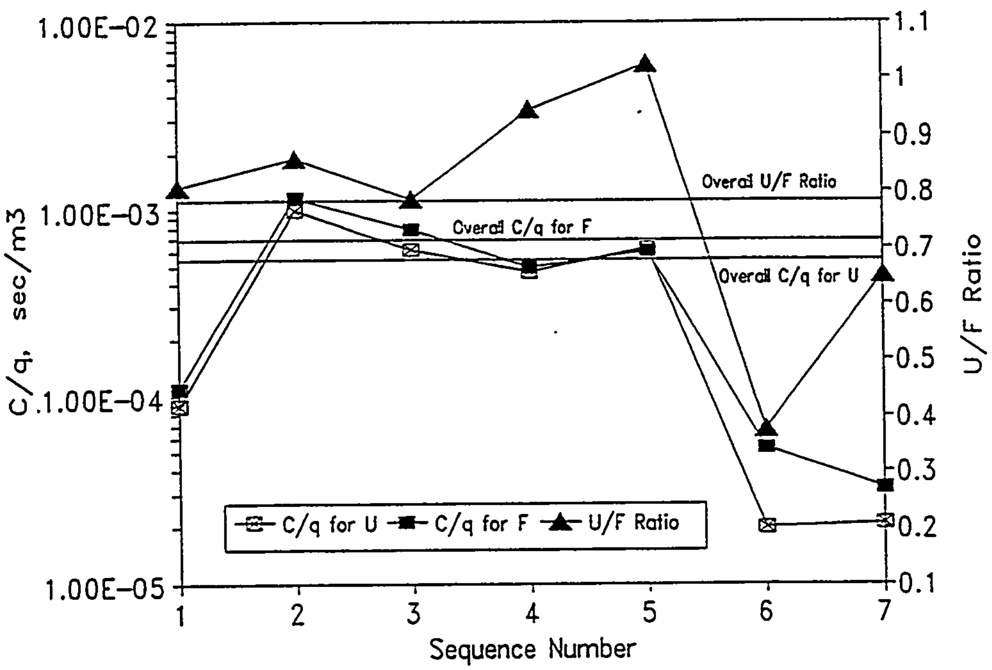

Fig. 5.16. C/q and U/F ratio versus sequence number at 20 m downwind, 6 m high, and 315° azimuth.

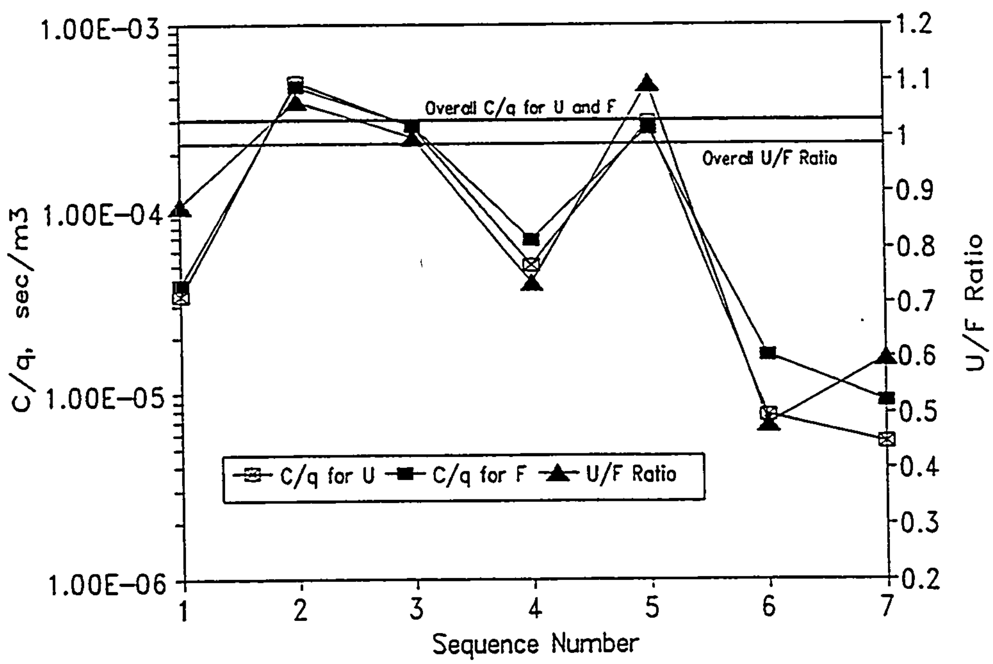

Fig. 5.17. C/q and U/F ratio versus sequence number at 40 m downwind, 8 m high, and 315° azimuth.

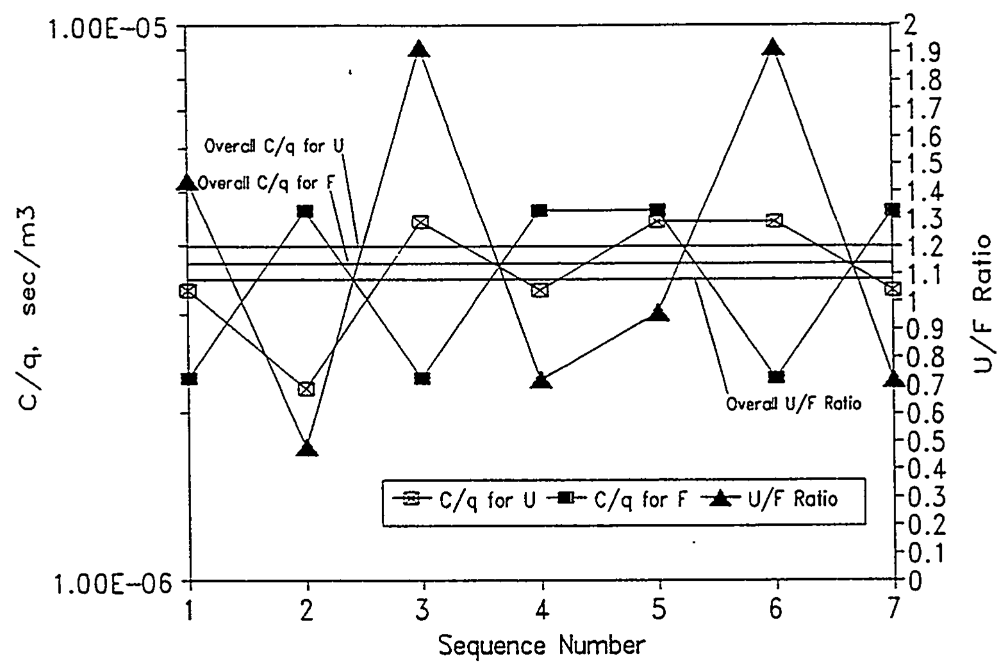

Fig. 5.18. C/q and U/F ratio versus sequence number at 40 m downwind, 15 m high, and 315° azimuth.

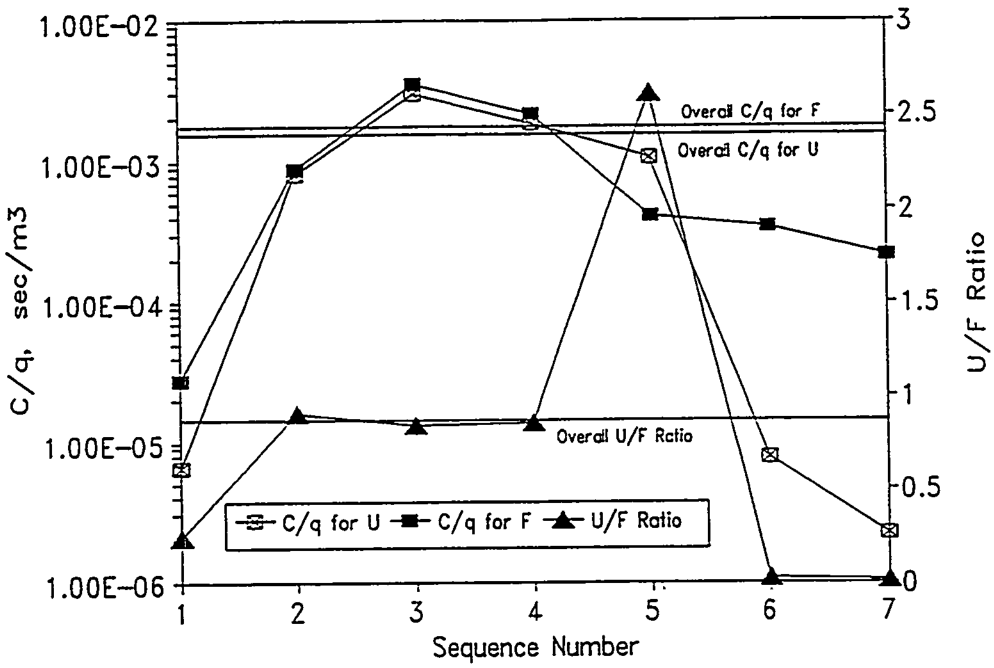

Fig. 5.19. C/q and U/F ratio versus sequence number at 20 m downwind, 1 m high, and 292.5° azimuth.

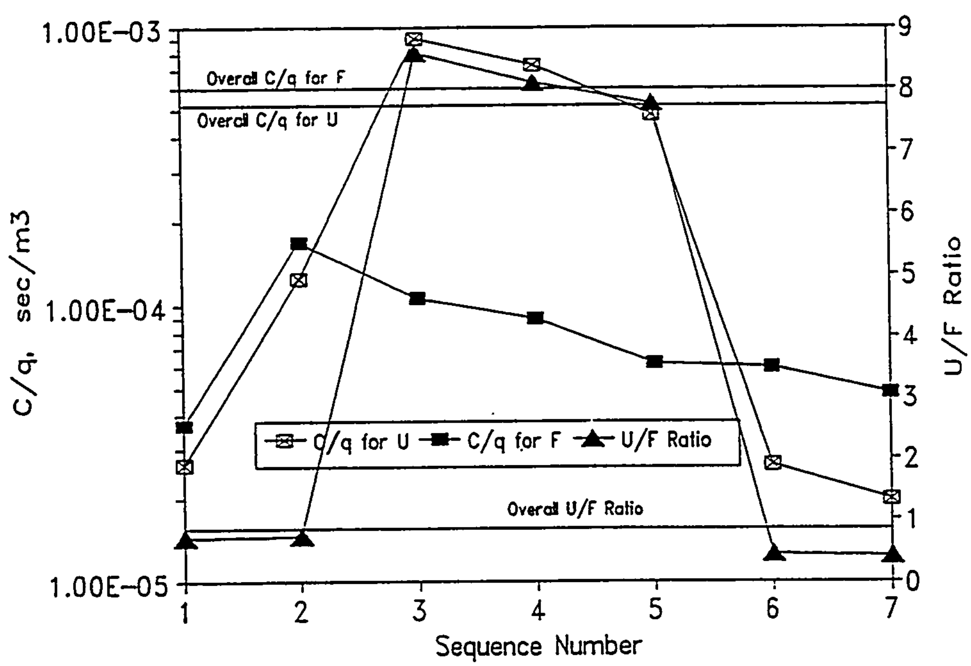

Fig. 5.20. C/q and U/F ratio versus sequence number at 40 m downwind, 1 m high, and 292.5° azimuth.

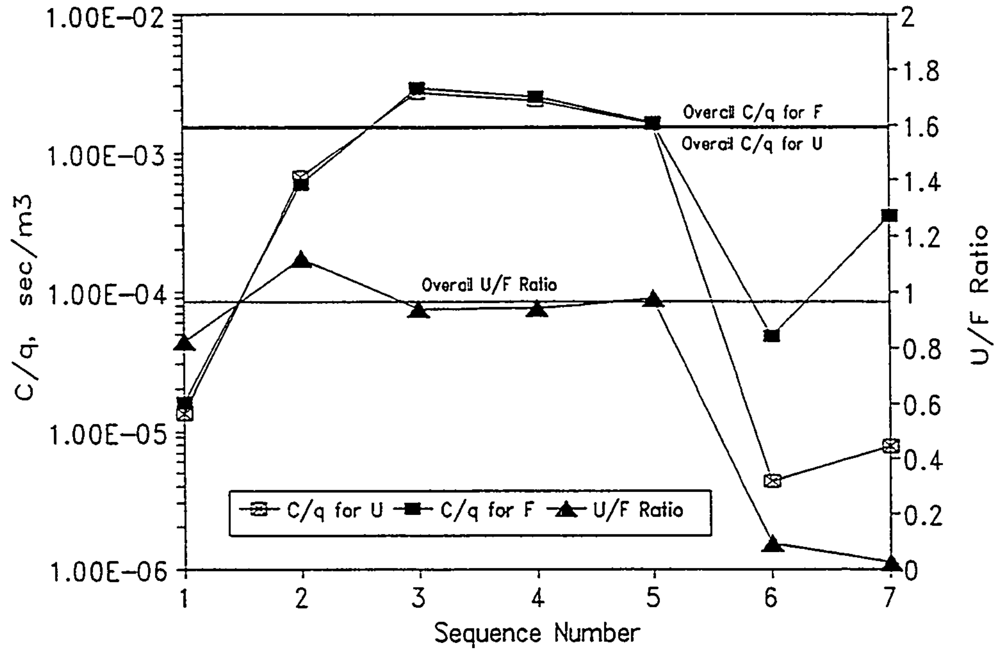

Fig. 5.21. C/q and U/F ratio versus sequence number at 20 m downwind, 3 m high, and 292.5° azimuth.

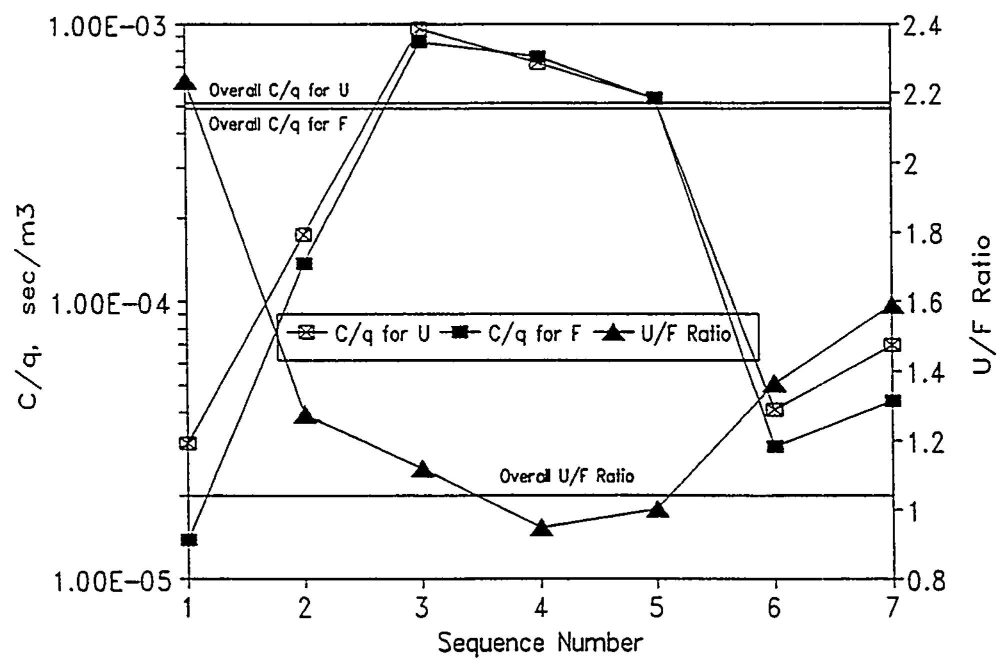

Fig. 5.22. C/q and U/F ratio versus sequence number at 40 m downwind, 3 m high, and 292.5° azimuth.

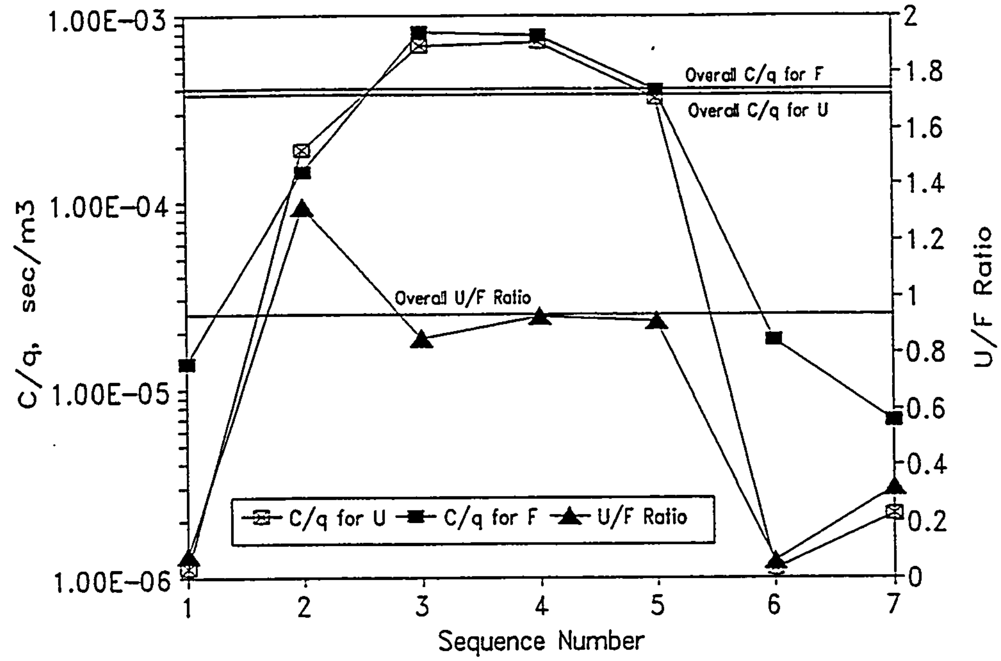

Fig. 5.23. C/q and U/F ratio versus sequence number at 20 m downwind, 6 m high, and 292.5° azimuth.

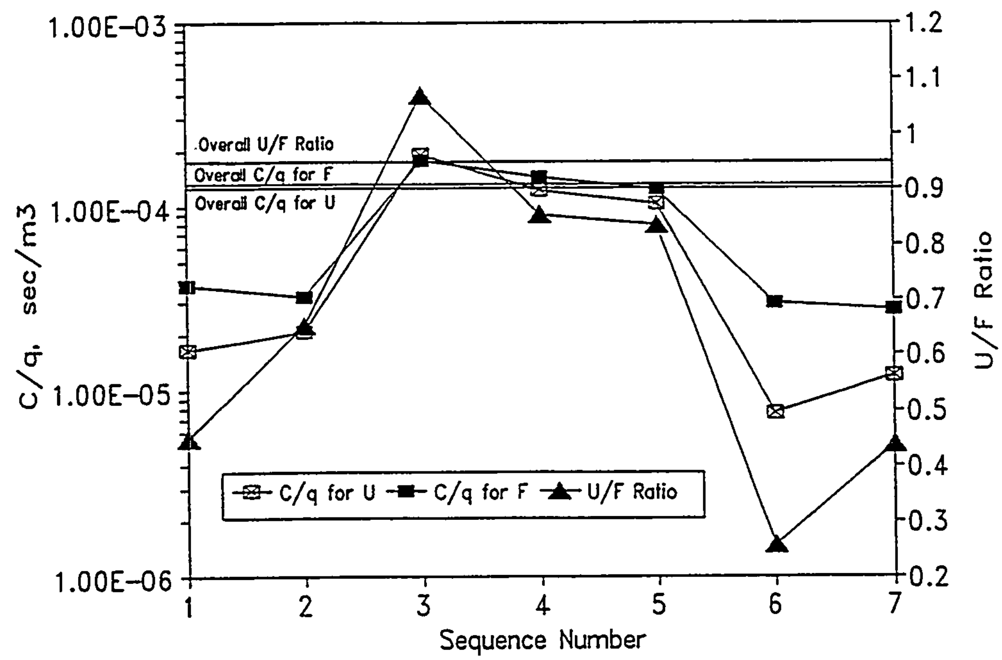

Fig. 5.24. C/q and U/F ratio versus sequence number at 40 m downwind, 8 m high, and 292.5° azimuth.

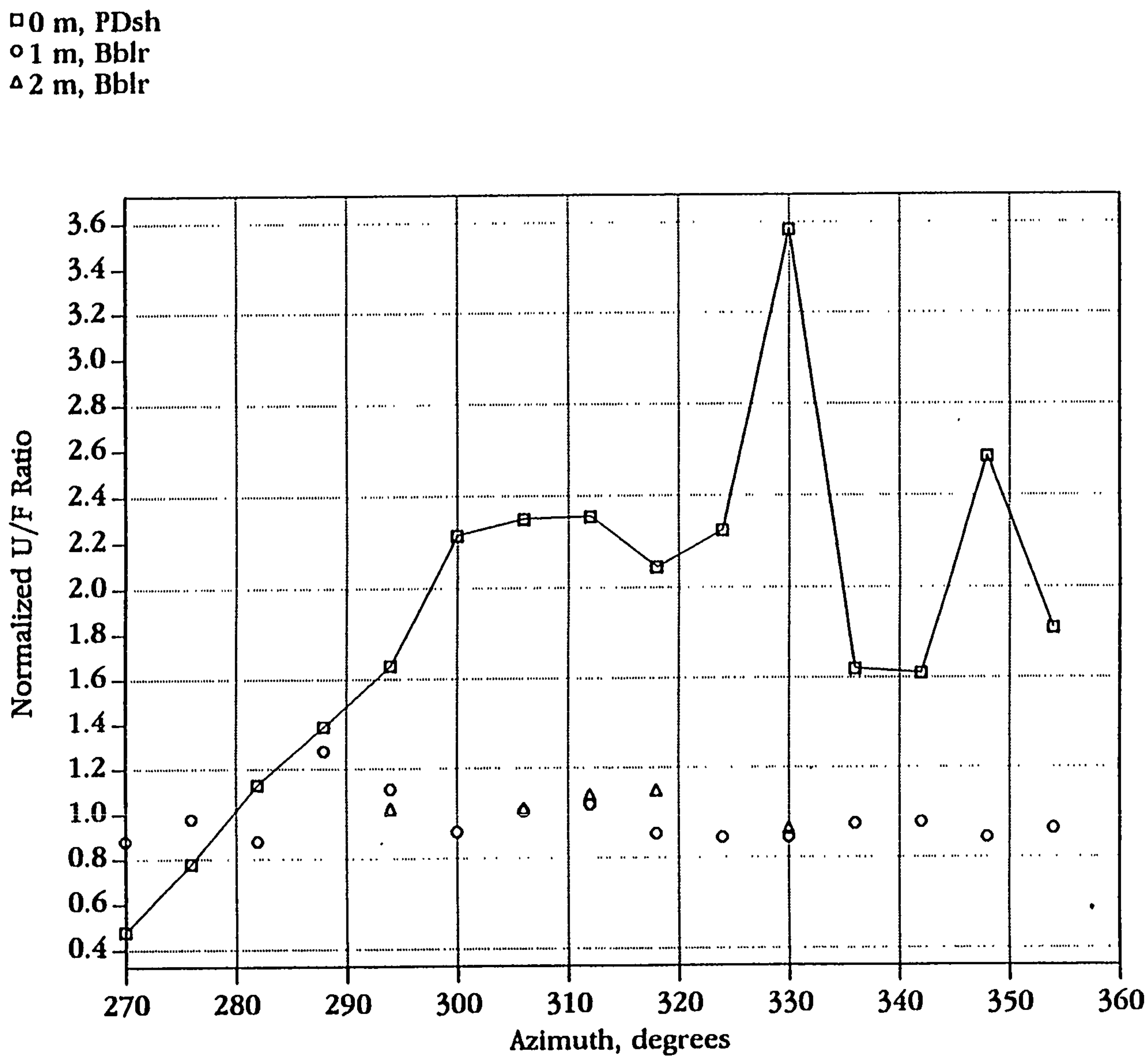

Fig. 5.25. Normalized U/F ratio versus azimuth at 10 m downwind.

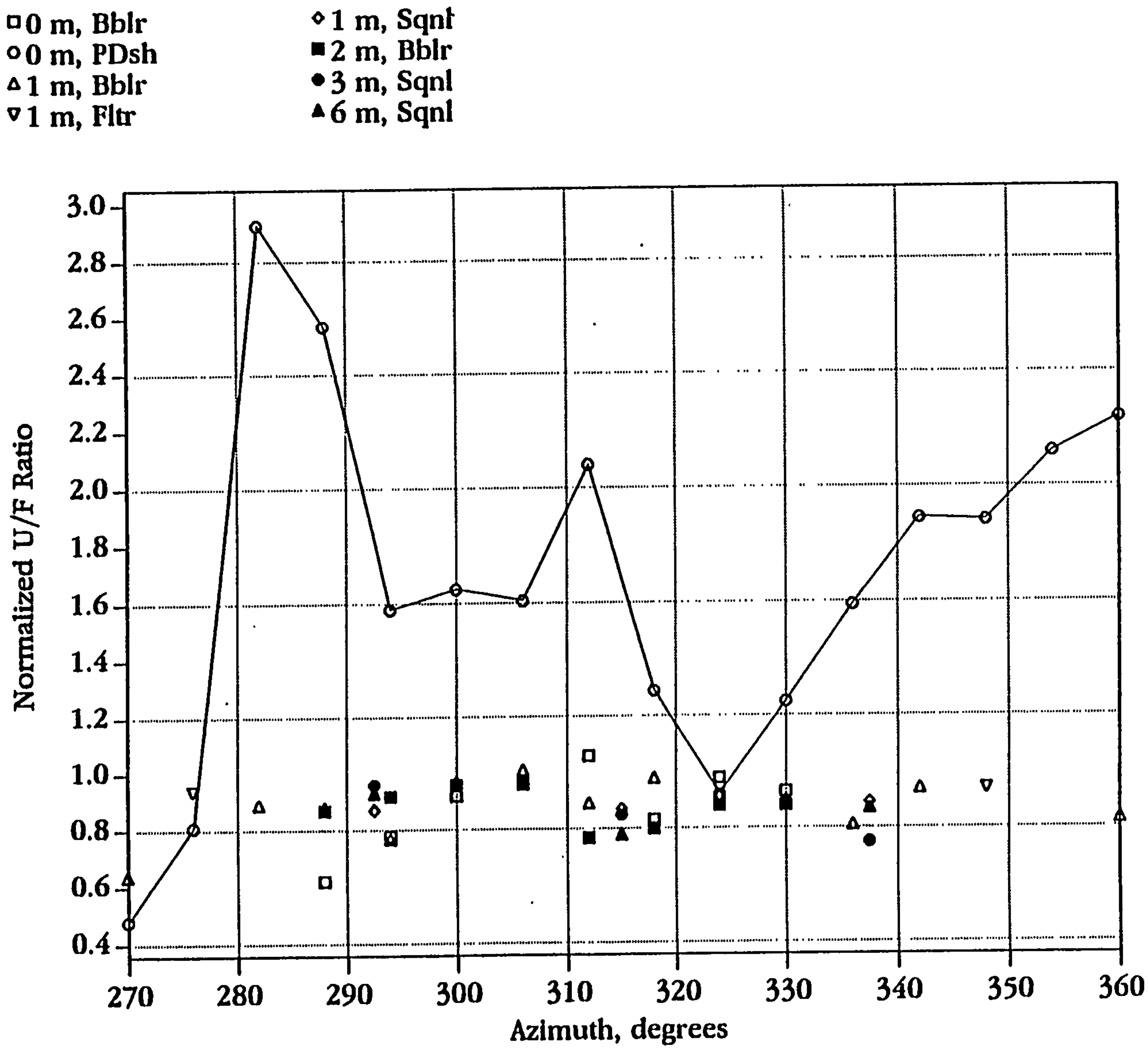

Fig. 5.26. Normalized U/F ratio versus azimuth at 20 m downwind.

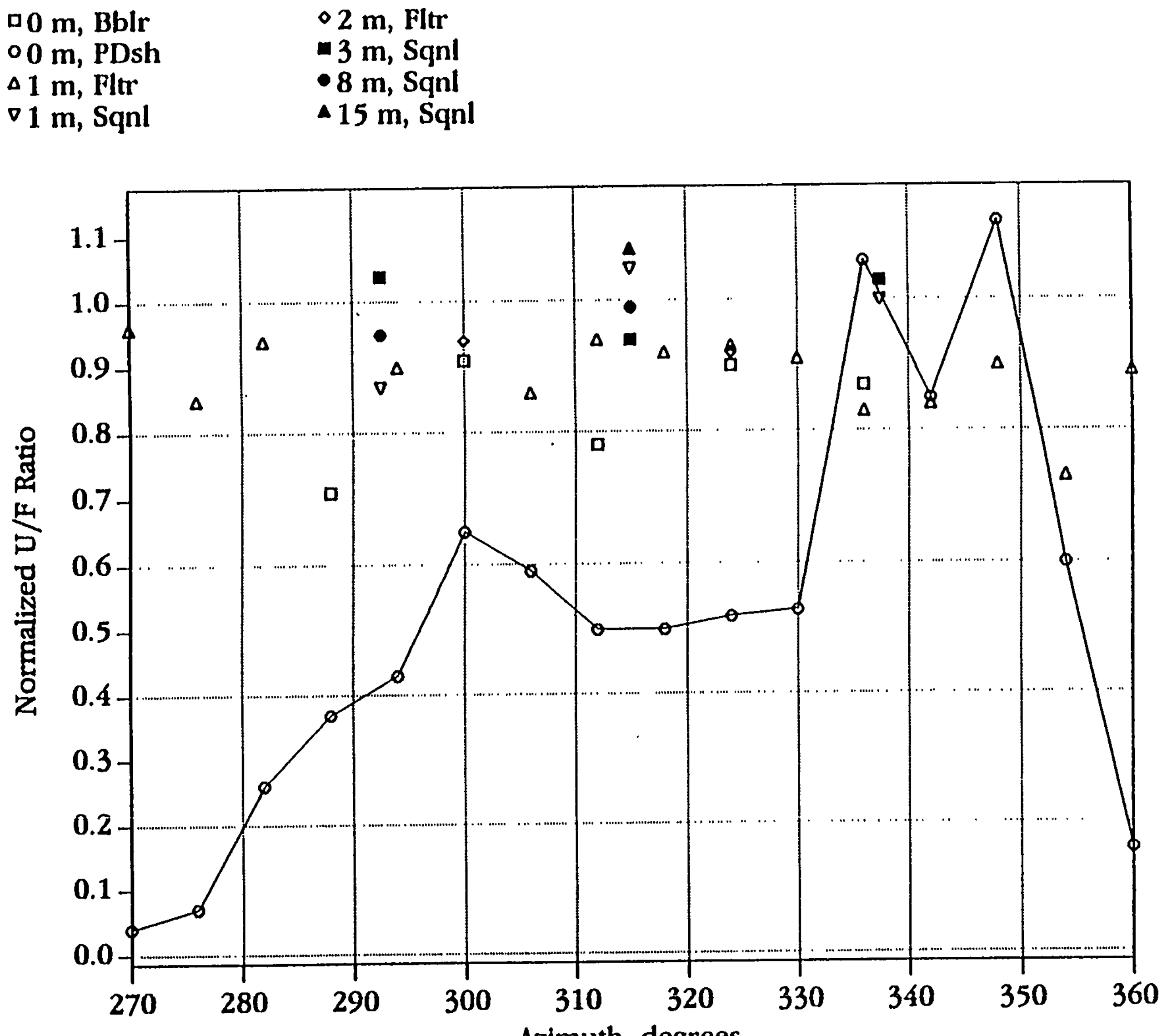

Fig. 5.27. Normalized U/F ratio versus azimuth at 40 m downwind.

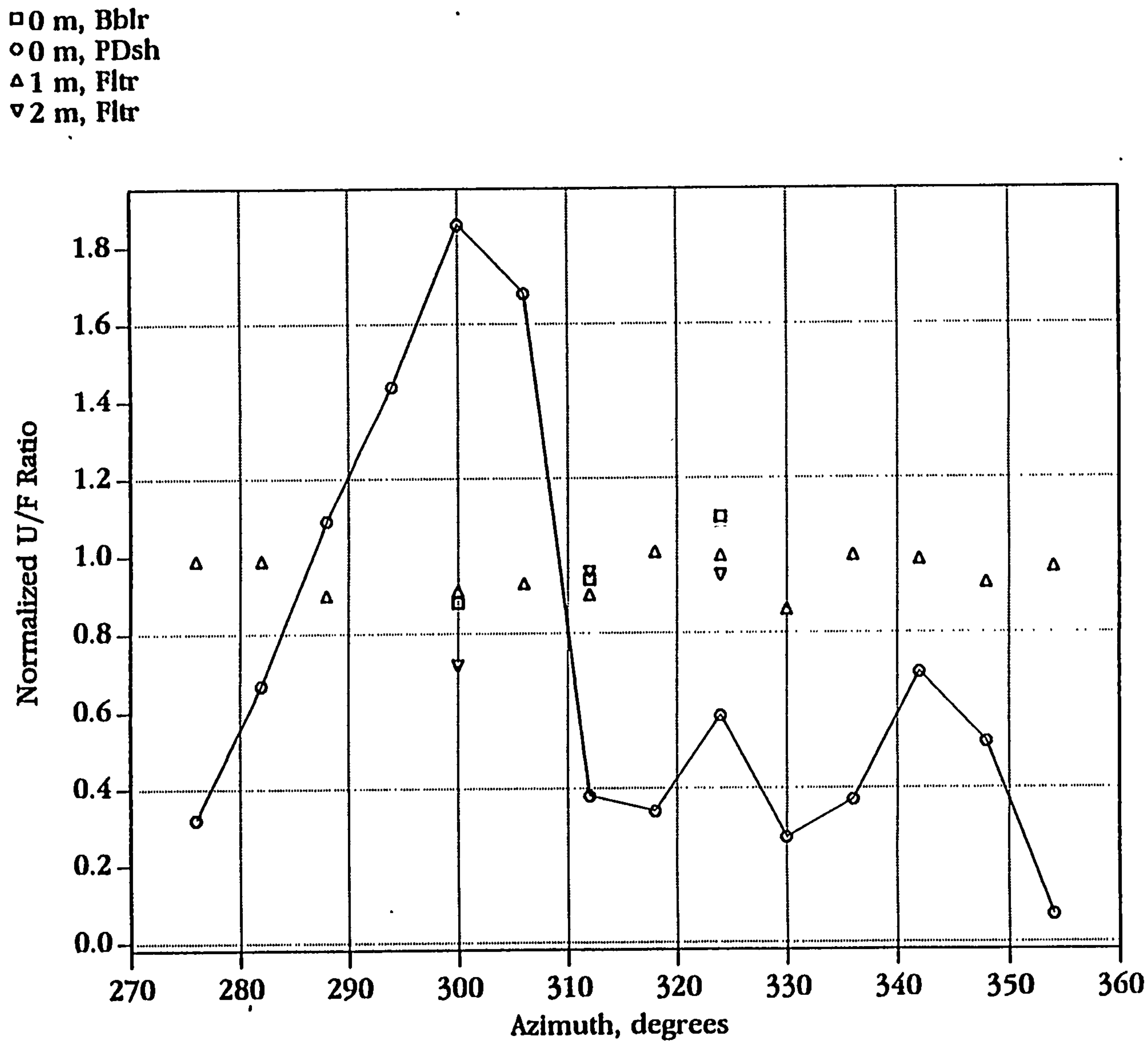

Fig. 5.28. Normalized U/F ratio versus azimuth at 70 m downwind.

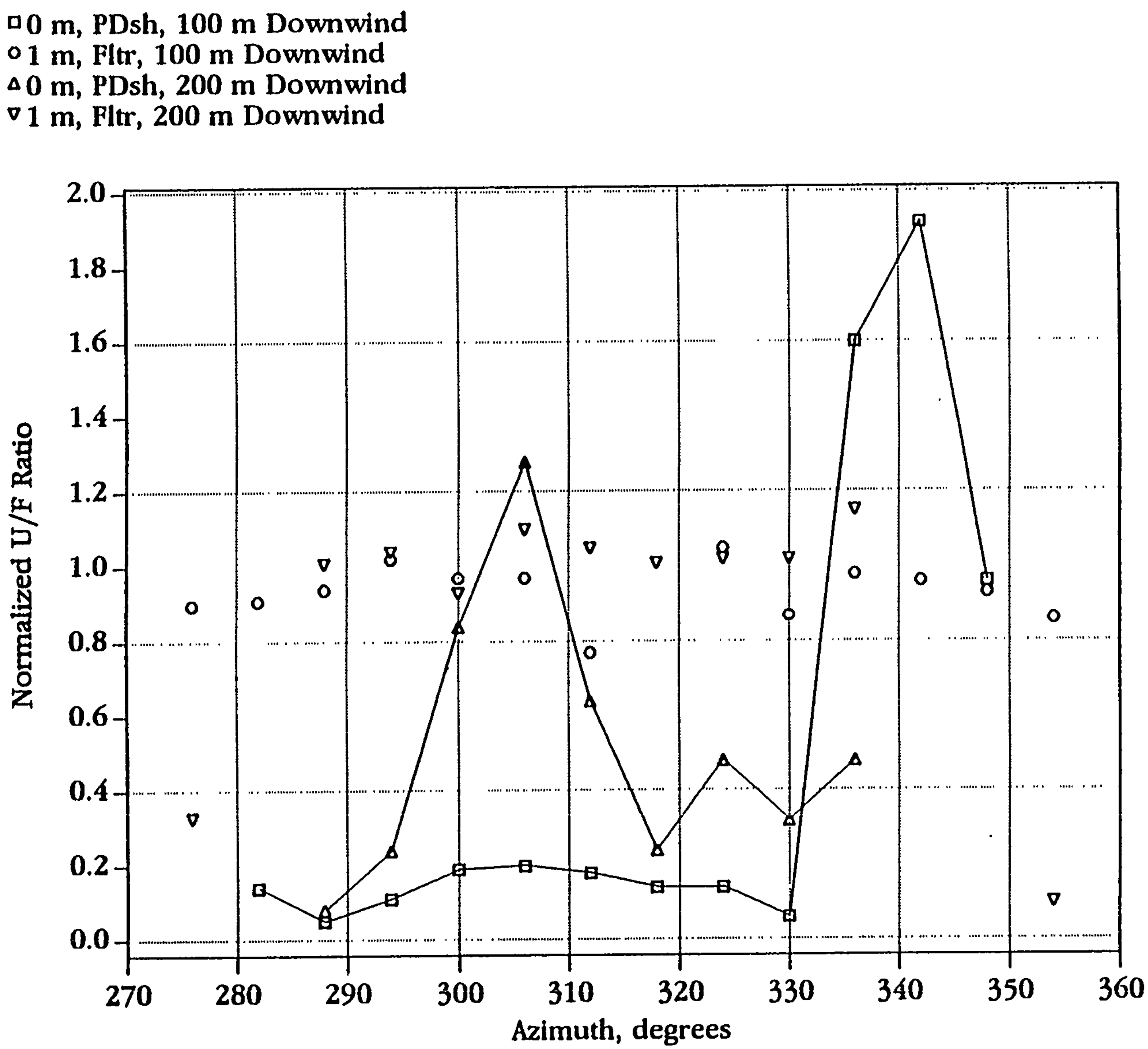

Fig. 5.29. Normalized U/F ratio versus azimuth at 100 and 200 m downwind.

The deposition data (petri dish) show a much broader range from about 0.05 to about 3.6 (average is 1.02). Since the discussion of the particle-size data in Sect. 5.6 implies the particles are primarily UO_2F_2 (R_{UF} = 3.0), the higher petri dish values of R_{UF} are reasonable and would be expected to correlate with the wind direction (the particles would tend to move directly with the wind and appear in smaller amounts off the main wind direction). However, no such correlation can be discerned. The wind direction during the test ranged between 295° and 325° (Table 2.1), but only the data at 10 m downwind showed petri dish R_{UF} values greater than 2.0 for these azimuths (Fig. 5.25). At other downwind distances, the petri dish R_{UF} values are less than 2.0 for these azimuths. These inconsistencies in R_{UF} values make the petri dish data suspect. The petri dish data at downwind distances greater than 20 m are definitely suspect since sand was found in most of the samples (Appendix E). R_{UF} values derived from the 1987 test (Just and Bloom, 1989, pp. 20 and 37) ranged from 0.47 to 2.45 for bubblers and filters (average was 1.04) and from 0.08 to 13.8 for the sequentials (average was 0.91). R_{UF} values derived from the 1986 test (Just, 1986, pp. 24 and 51) ranged from 0.005 to 2.59 for bubblers and filters and from 0.02 to 17.1 for the sequentials. No average R_{UF} values were computed from the 1986 test data but the data appeared to cluster about 1.0.

5.4 R_{UF} AS A FUNCTION OF CONCENTRATION

R_{UF} values derived from bubblers, filters, and sequentials, are shown as functions of uranium concentration in Fig. 5.30 and as functions of fluorine concentration in Fig. 5.31. The sequentials values show a great deal of scatter at all concentrations but tend to cluster near 1.0. The values derived from the bubblers and filters are all near 1.0 except for two filters values at low concentrations. There is no discernible function of concentration. R_{UF} values derived from the 1986 and 1987 tests (Just, 1986, pp. 24 and 51; Just and Bloom, 1989, pp. 20 and 37) seemed to indicate a trend of increasing R_{UF} with increasing uranium concentration. However, the values from all three tests show too much scatter to verify any trends.

5.5 DEPOSITION AS A FUNCTION OF DOWNWIND DISTANCE AND AZIMUTH

Values of deposition, expressed as D/q, are shown in Figs. 5.32 and 5.33 as a function of azimuth. The general trends of the data as a function of azimuth for 10, 20, and 40 m downwind (Fig. 5.32), show peak values in the 300° to 330° interval, which are consistent with an average wind direction in this same interval. However, no such trends are evident in the data for 70, 100, and 200 m downwind (Fig. 5.33). Similarly, the data for 10, 20, and 40 m downwind imply the expected trend of decreasing deposition with increasing distance, but such trends are not evident in the data for 70, 100, and 200 m downwind. At 10 and 20 m downwind, the uranium deposition is greater than fluorine, but the reverse is true for greater downwind distances. Sand was found in most of the petri dish samples at downwind distances greater than 20 m (Appendix E); therefore, the erratic behavior at these distances may be due to the errors introduced by the sand.

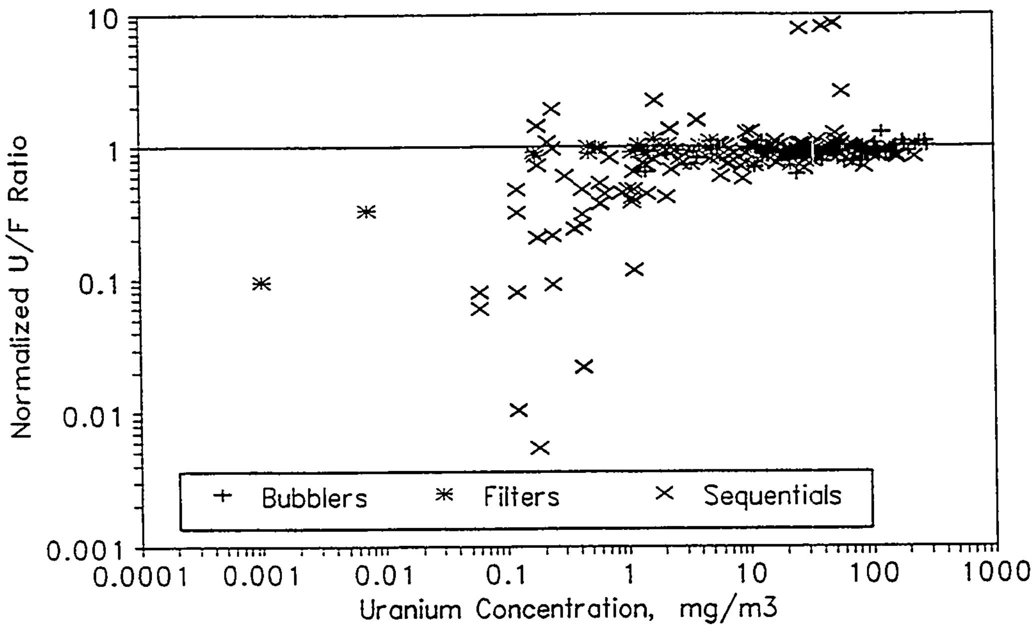

Fig. 5.30. Normalized U/F ratio versus uranium concentration.

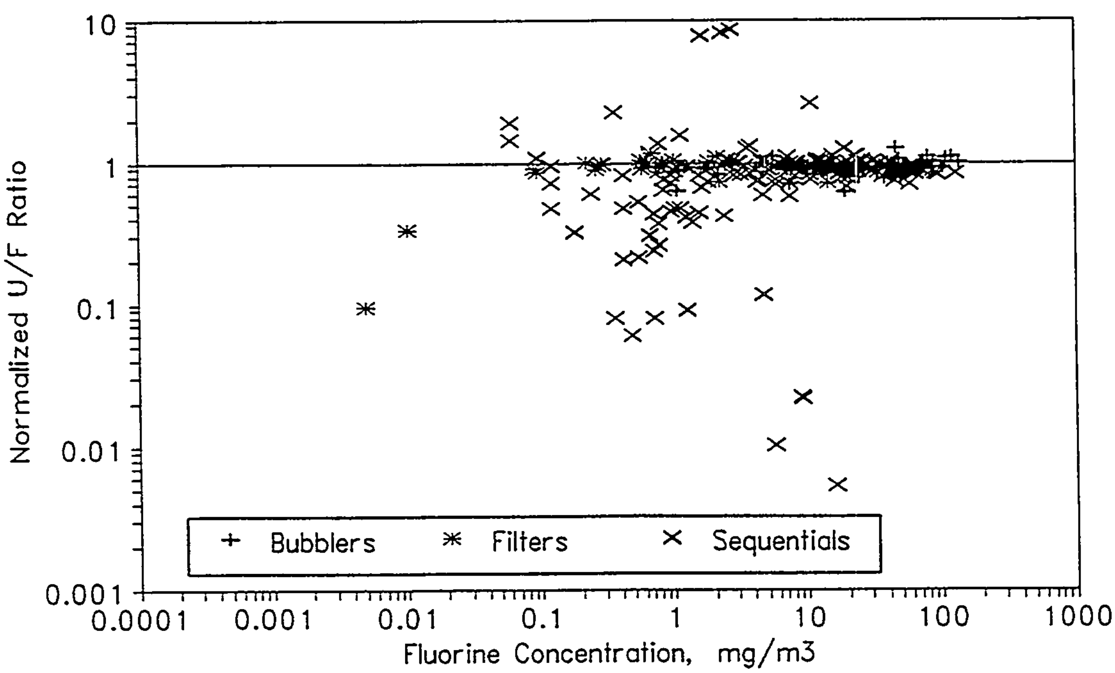

Fig. 5.31. Normalized U/F ratio versus fluorine concentration.

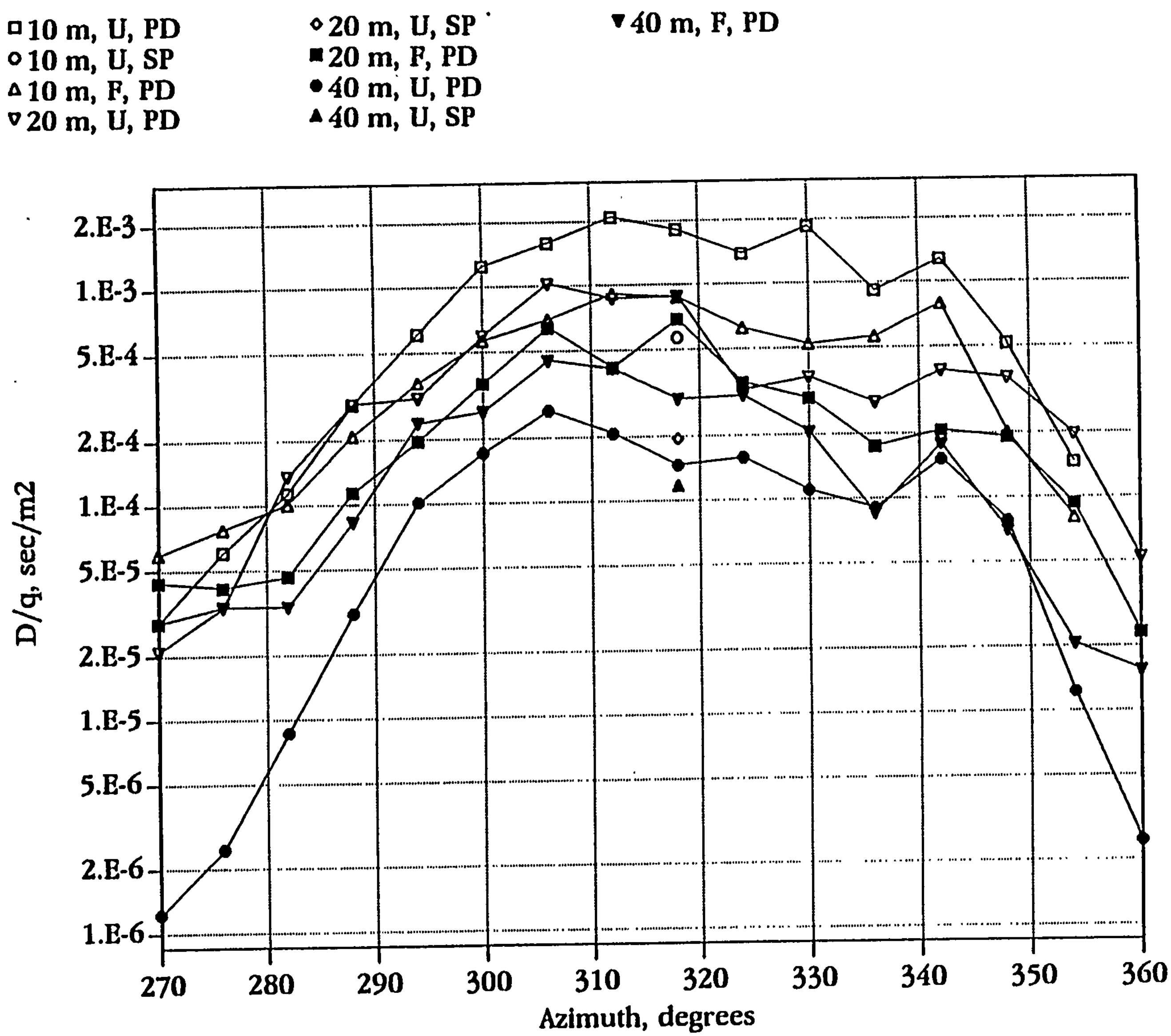

Fig. 5.32. D/q versus azimuth at 10, 20, and 40 m downwind.

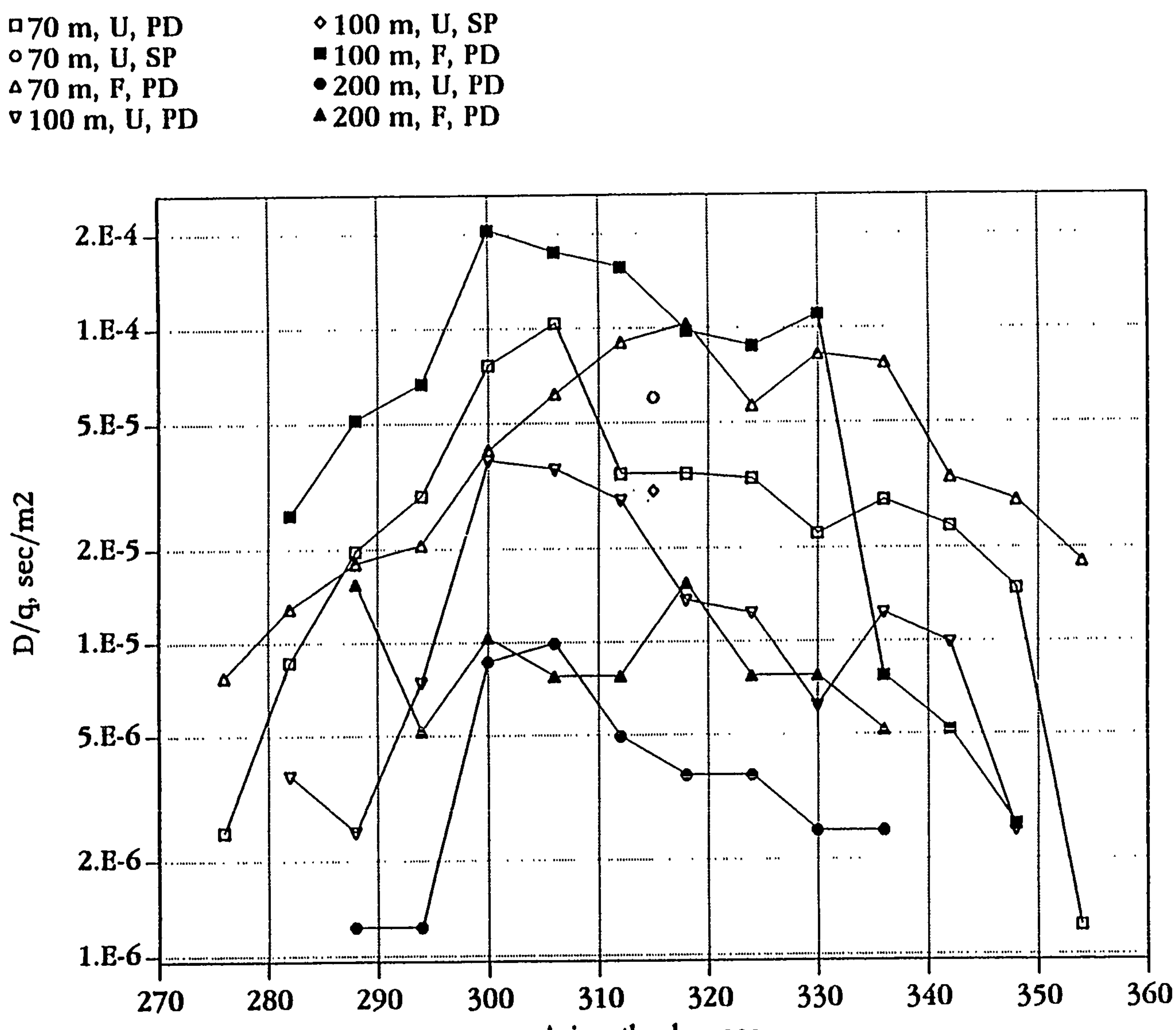

Fig. 5.33. D/q versus azimuth at 70, 100, 200 m downwind.

Most of the data in Figs. 5.32 and 5.33 are from petri dishes on the ground, but a few points are based on the uranium deposited in Scotch paper collectors at 1- and 2-m heights. The Scotch paper deposition values are significantly smaller than the corresponding petri dish values at 10 and 20 m downwind, about the same at 40 m, and significantly larger at 70 and 100 m. The discrepancies at all downwind distances may be due to different sampling heights, while discrepancies at downwind distances greater than 20 m may be due to the errors introduced by the sand. Possible systematic errors in the methods may also account for the discrepancies.

5.6 PARTICLE SIZE DISTRIBUTION AND R_{UF} AS A FUNCTION OF PARTICLE SIZE

Figures 5.34–5.38 show the mass fraction of uranium and fluorine associated with each of nine classes of particle sizes, as measured with Andersen Impact samplers. The particle sizes in microns (μm) are listed below:

- 0 to 0.4
- 0.4 to 0.7
- 0.7 to 1.1
- 1.1 to 2.1
- 2.1 to 3.3
- 3.3 to 4.7
- 4.7 to 5.8
- 5.8 to 9.0
- >9.0

Figures 5.34–5.38 also show the cumulative mass fractions (fraction greater than the indicated size) and values of the U/F mole ratio (R_{UF}) associated with each size class. The mass mean particle size (cumulative mass fraction is 0.50) for both uranium and fluorine is about 3 μm with the fluorine size being generally larger. For both uranium and fluorine, the largest mass occurs with particles in the range of 1.1 to 3.3 μm. Except for the data at 40 m downwind, a secondary peak in the mass fraction for fluorine occurs with particles greater than 9.0 μm.

Except for the data at 40 m downwind, the R_{UF} associated with the particles in the range of 1.1 to 3.3 μm is about of 3.0, which implies that the particles in this size range are primarily UO_2F_2 (R_{UF} = 3.0). The R_{UF} associated with the particles greater than 9.0 μm is approximately 0.2 to 0.5, which implies that these larger particles contain very little uranium. The larger particles may be HF associated with, or reacted with, dust or water droplets. The R_{UF} of the smallest particles (less than 0.7 μm) ranges between 0.02 to 2.2, which may indicate that the smaller particles are UO_2F_2 associated with HF.

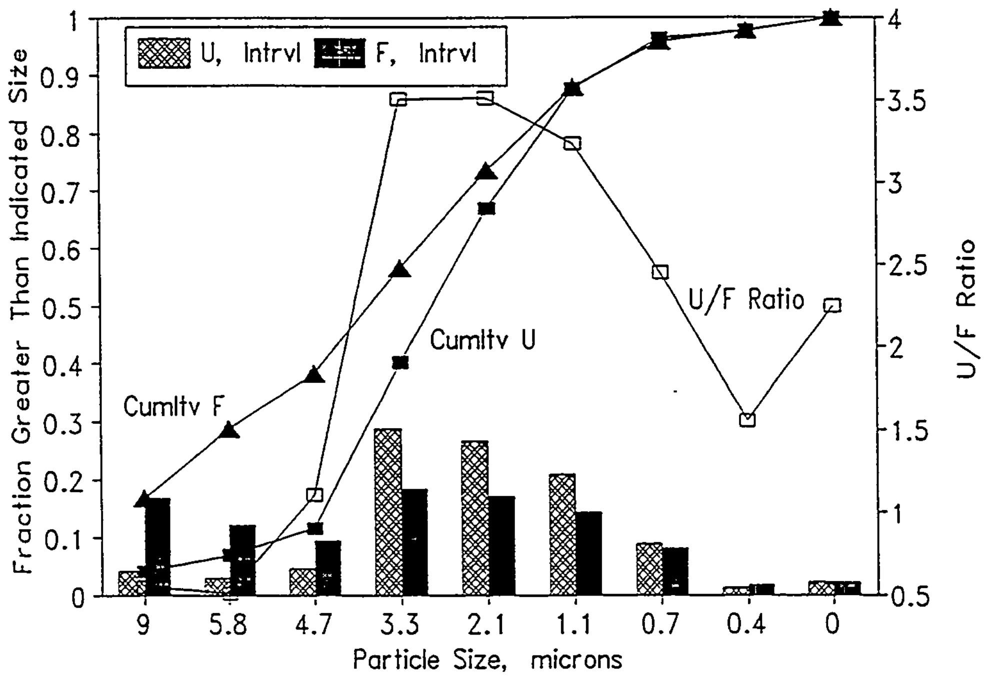

Fig. 5.34. Particle size distribution at 10 m downwind, 2 m high, and 318° azimuth.

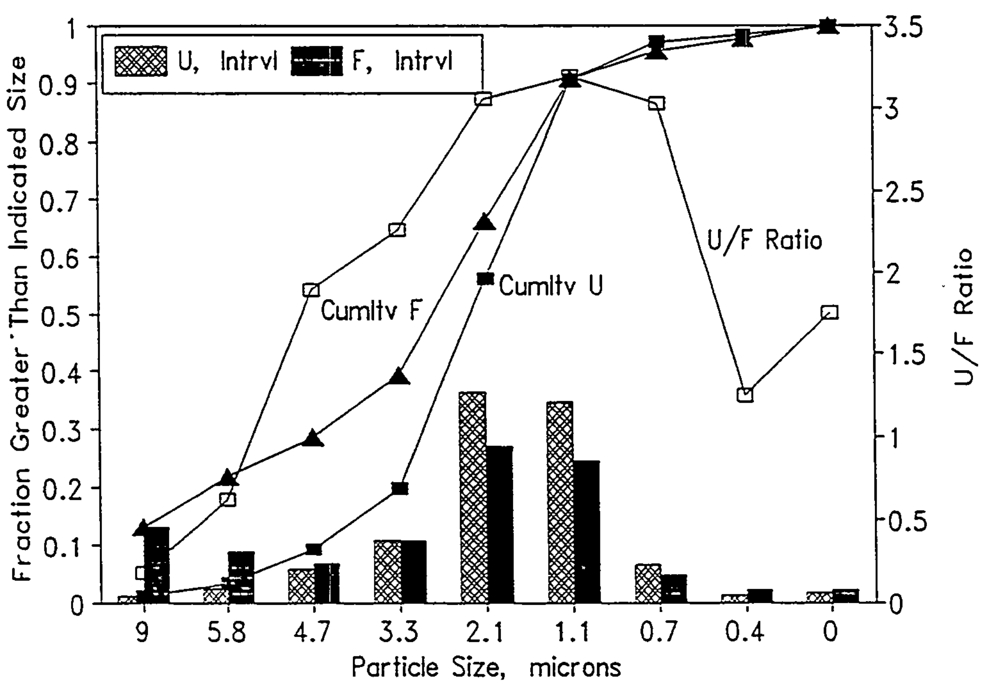

Fig. 5.35. Particle size distribution at 20 m downwind, 1 m high, and 318° azimuth.

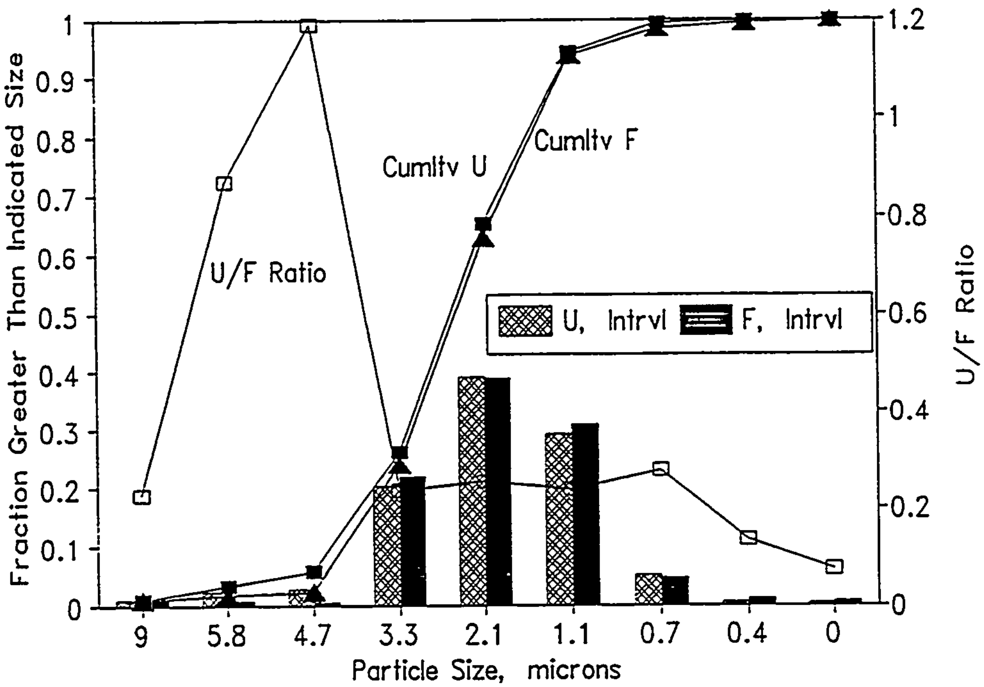

Fig. 5.36. Particle size distribution at 40 m downwind, 1 m high, and 318° azimuth.

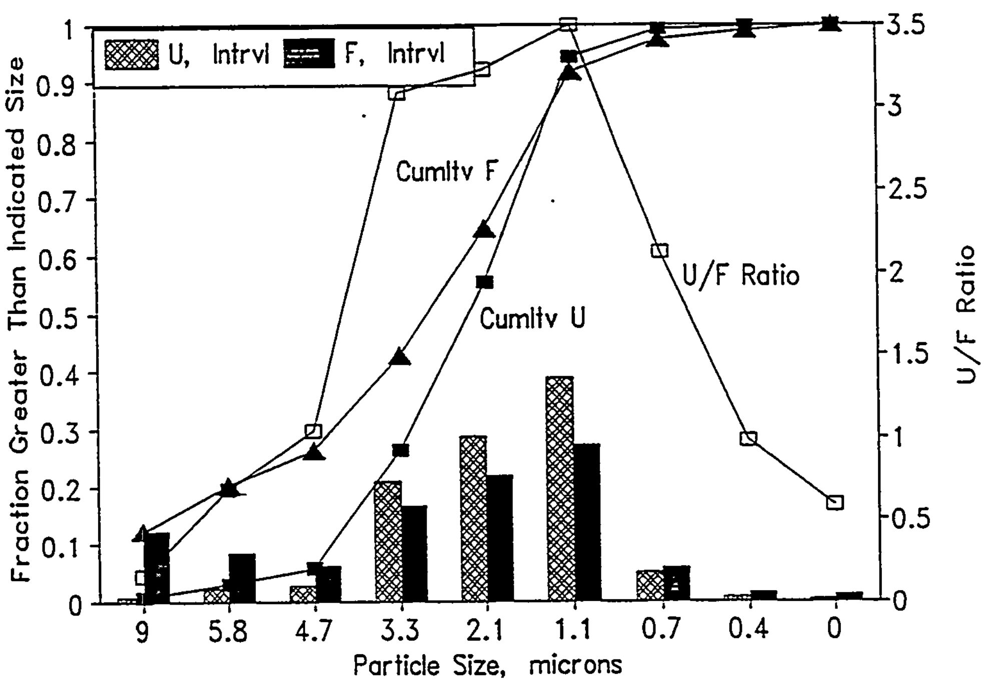

Fig. 5.37. Particle size distribution at 70 m downwind, 1 m high, and 315° azimuth.

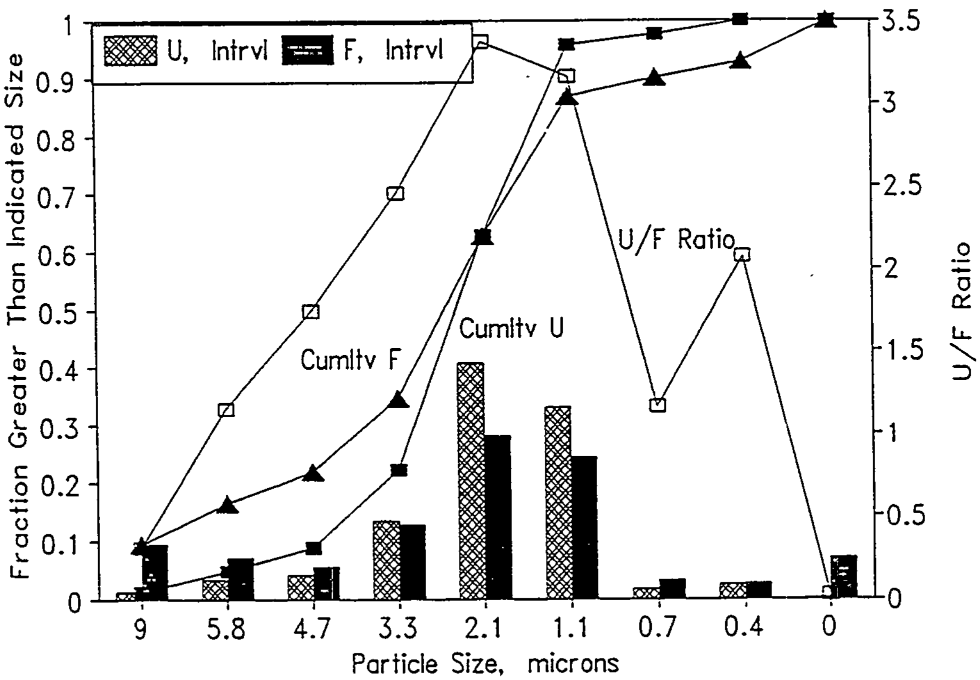

Fig. 5.38. Particle size distribution at 100 m downwind, 1 m high, and 315° azimuth.

6. SUMMARY AND CONCLUSIONS

A controlled uranium hexafluoride (UF_6) release test was conducted on June 5, 1989, during which 73.1 kg of UF_6 vapor was released over a time interval of 15 min. The information collected included meteorological data, measurements of uranium and fluorine concentrations, particle size distribution information, deposition data, visual data (photographs and a videotape), and temperature measurements within the plume close to the release point. This information and derived values of normalized concentrations (C/q), air concentrations, and normalized uranium to fluorine mole ratios (R_{UF}) were provided to Energy Systems. This report contains an analysis of the data collected during this test and a comparison of these data with the predictions of the UF_6 dispersion model developed by Energy Systems.

Some problems were encountered in interpreting and analyzing the data. There is some uncertainty in interpreting the sign of the temperature difference between 2 and 28 m, which strongly affects one of the criteria for evaluating atmospheric stability. Three additional criteria were applied and two of them indicated B stability. No data were reported for 7 of the 65 filters samplers, and there is some uncertainty about the locations of the filters at a distance of 40 m and height of 2 m. Values of C/q, R_{UF}, and C were recalculated in this report, and a number of inconsistencies were discovered in the tables provided. Estimates of precision for the amount of uranium collected by the bubbler samplers did not follow the estimating rules included with the data, but the estimates of precision in all of the derived values were consistent with these rules. These precision estimates were not used in the recalculations. Also, the derived values from uranium and fluorine collected by the sequentials samplers, seemed to be divided by a factor of 1.1. No reason was given for this factor, nor is it obvious from the information provided. Despite this uncertainty, the factor was used in the recalculations. Even with the inclusion of this factor for the sequentials, many of the recalculated values did not equal the corresponding values provided, but it is believed that these discrepancies are due to arithmetic and typographic errors.

Several of the petri dishes are questionable because sand was found in the samples. Quantitative data could not be obtained from the images from the video cameras because the exact location of the cameras were not known with respect to landmarks (sampling towers) visible in the pictures. The measured temperatures showed rapid fluctuations with time that could not be interpreted; consequently, no analyses of the temperature data are given. No location contained more than one sampling device to measure the concentrations; consequently, direct comparison of results from using different sampling devices was not possible. However, direct comparisons between bubblers and filters from an earlier test (April 10, 1987) indicated a range of 0.480 to 1.304 in the ratio of the bubbler to filter results.

The tabulated and plotted values of experimentally derived C/q generally indicate fluorine and uranium disperse in a similar manner, with the uranium values being slightly lower than the fluorine values. The differences are attributed to differences in plume depletion rates, which are proportional to deposition velocities. Experimentally derived deposition velocities range from about 9×10^{-5} to 2×10^{-2} m/s for uranium and 6×10^{-5} to 5×10^{-3} m/s for fluorine. The C/q plots imply that the mean wind direction during the release was about 306° rather than 316° as indicated by the meteorological data, but there is too much scatter in the data to be certain. Variations in the wind direction were within the 300° to 330° interval.

The C/q values simulated using the Energy Systems model are in reasonable agreement with the experimentally derived values for heights of 0 to 3 m near the centerline of the plume, but deviate significantly at azimuths far from the centerline and at heights above 3 m. The deviations are primarily attributed to simulated horizontal dispersion coefficients being too small and vertical dispersion coefficients being too large. This is a characteristic fault with models that depend on the Pasquill-Gifford dispersion coefficients when they are applied to ground-hovering plumes. Another deviation is that the simulated C/q values for uranium are slightly larger than the fluorine values because the simulated deposition velocity for fluorine (0.0514 m/s) was greater than for uranium (4.97×10^{-4} m/s). The Energy Systems model could have input dispersion coefficients and deposition velocities that may have made the computed results agree much closer with the experimental data, but this was not considered a fair test of the model.

Plots of C/q and R_{UF} as functions of time were derived from the sequentials samplers and these values appear to generally correlate with the wind direction during the test. The expected average value for R_{UF} and most of the experimentally-derived values taken over the entire duration of the release are slightly less than 1.0. Higher R_{UF} values seem to indicate a higher percentage of particles than the lower R_{UF} values. It seems reasonable that the particles would tend to move directly with the wind and appear in smaller amounts off the main wind direction. Consequently, the R_{UF} values would tend to show peak values at about the same time as the peak C/q values. Indications of errors in the sequential results are R_{UF} values much greater than 3.0, the unexplained factor of 1.1 mentioned above, and the fact that the sum of the weights collected in 3-min intervals (sequences 1–7) were less than the weights collected for the entire duration of the release (sequence 0).

Values of R_{UF} derived from the bubblers, filters, and sequence 0 of the sequentials show values ranging from about 0.6 to about 1.2, with most of the values between 0.8 and 1.0. The deposition data (petri dish) show a much broader range from about 0.05 to about 3.6. The petri dish data are suspect, especially the data at downwind distances greater than 20 m for which sand was found in most of the samples.

Experimentally derived values of deposition at 10, 20, and 40 m downwind show peak values in the 300° to 330° azimuth interval which is consistent with an average wind direction in this same interval. Also, these data show the expected trend of decreasing deposition with increasing distance. However, the data for 70, 100, and 200 m downwind show erratic behavior, possibly because sand was in most of the petri dish samples at downwind distances greater than 20 m. Most of the deposition data are from petri dishes but a few points are based on the uranium deposited on Scotch paper collectors. The Scotch paper deposition values are significantly smaller than the corresponding petri dish values at 10 and 20 m downwind, about the same at 40 m, and significantly larger at 70 and 100 m.

Data from Andersen Impact samplers indicate that the mass mean particle size for both uranium and fluorine is about 3 μm with peak masses in the range of 1.1 to 3.3 μm. A secondary peak for fluorine seems to occur with particles greater than 9.0 μm. The particles in the range of 1.1 to 3.3 μm seem to be primarily UO_2F_2 while the particles greater than 9.0 μm may be HF associated with, or reacted with, dust or water droplets.

On the basis of the comparisons between the simulated results and the experimental data shown in Figs. 5.1–5.5, it is recommended that the Energy Systems model can be used, with some modification, to simulate relatively dilute releases of gaseous UF_6. However, it is recommended that the deposition velocity for fluorine be reduced to a value (e.g., 1×10^{-4} m/s) slightly smaller than that for uranium. Such a value would be consistent with the particle sizes measured in these tests. For concentrated releases of gaseous UF_6, the dispersion coefficients would have to be modified to better simulate ground-hovering plumes.

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Appendix A

DATA FROM BUBBLERS

Table A.1. Data from bubblers at 10 m downwind and 1 m height

Downwind distance (m)	Height (m)	Angle (degrees)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
10	1	354	0.037	0.019	0.004	0.001	2.69E-05	2.89E-05	0.93	1.48E+00	7.59E-01
10	1	348	0.052	0.028	0.006	0.001	3.78E-05	4.25E-05	0.89	2.08E+00	1.12E+00
10	1	342	0.355	0.178	0.025	0.004	2.58E-04	2.70E-04	0.96	1.42E+01	7.11E+00
10	1	336	1.216	0.61	0.087	0.015	8.85E-04	9.27E-04	0.95	4.86E+01	2.44E+01
10	1	330	2.202	1.185	0.166	0.029	1.60E-03	1.80E-03	0.89	8.80E+01	4.74E+01
10	1	324	2.173	1.17	0.148	0.028	1.58E-03	1.78E-03	0.89	8.69E+01	4.68E+01
10	1	318	3.553	1.868	0.243	0.045	2.59E-03	2.84E-03	0.91	1.42E+02	7.47E+01
10	1	312	4.758	2.2	0.35	0.053	3.46E-03	3.34E-03	1.04	1.90E+02	8.79E+01
10	1	306	5.79	2.736	0.42	0.066	4.21E-03	4.16E-03	1.01	2.31E+02	1.09E+02
10	1	300	4.11	2.149	0.294	0.052	2.99E-03	3.27E-03	0.92	1.64E+02	8.59E+01
10	1	294	4.583	1.986	0.332	0.048	3.34E-03	3.02E-03	1.11	1.83E+02	7.94E+01
10	1	288	3.1	1.163	0.218	0.028	2.26E-03	1.77E-03	1.28	1.24E+02	4.65E+01
10	1	282	1.252	0.679	0.093	0.016	9.11E-04	1.03E-03	0.88	5.00E+01	2.71E+01
10	1	276	0.801	0.393	0.059	0.01	5.83E-04	5.97E-04	0.98	3.20E+01	1.57E+01
10	1	270	0.356	0.194	0.025	0.005	2.59E-04	2.95E-04	0.88	1.42E+01	7.75E+00

Table A.2. Data from bubblers at 10 m downwind and 2 m height

Downwind distance (m)	Height (m)	Angle (degrees)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
10	2	330	5.039	2.594	0.371	0.063	3.67E-03	3.94E-03	0.93	2.01E+02	1.04E+02
10	2	318	6.895	3.016	0.507	0.073	5.02E-03	4.58E-03	1.10	2.76E+02	1.21E+02
10	2	312	6.219	2.754	0.457	0.067	4.53E-03	4.18E-03	1.08	2.49E+02	1.10E+02
10	2	306	7.198	3.39	0.526	0.082	5.24E-03	5.15E-03	1.02	2.88E+02	1.35E+02
10	2	294	3.967	1.866	0.283	0.045	2.89E-03	2.84E-03	1.02	1.59E+02	7.46E+01

Table A.3. Data from bubblers at 20 m downwind and 0 m height

Downwind distance (m)	Height (m)	Angle (degrees)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	0	330	1.418	0.734	0.109	0.018	1.03E-03	1.12E-03	0.93	5.67E+01	2.93E+01
20	0	324	2.059	1.002	0.147	0.024	1.50E-03	1.52E-03	0.98	8.23E+01	4.00E+01
20	0	318	2.018	1.165	0.155	0.028	1.47E-03	1.77E-03	0.83	8.07E+01	4.66E+01
20	0	312	2.707	1.228	0.198	0.03	1.97E-03	1.87E-03	1.06	1.08E+02	4.91E+01
20	0	306	3.605	1.783	0.265	0.043	2.62E-03	2.71E-03	0.97	1.44E+02	7.13E+01
20	0	300	2.616	1.368	0.18	0.033	1.90E-03	2.08E-03	0.92	1.05E+02	5.47E+01
20	0	294	1.789	1.097	0.123	0.027	1.30E-03	1.67E-03	0.78	7.15E+01	4.38E+01
20	0	288	0.625	0.484	0.046	0.012	4.55E-04	7.35E-04	0.62	2.50E+01	1.93E+01

Table A.4. Data from bubblers at 20 m downwind and 1 m height

Downwind distance (m)	Height (m)	Angle (degrees)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	1	360	0.095	0.055	0.011	0.001	6.91E-05	8.36E-05	0.83	3.80E+00	2.20E+00
20	1	342	0.77	0.393	0.057	0.01	5.60E-04	5.97E-04	0.94	3.08E+01	1.57E+01
20	1	336	0.902	0.536	0.068	0.01	6.56E-04	8.14E-04	0.81	3.61E+01	2.14E+01
20	1	330	0.897	0.478	0.065	0.012	6.53E-04	7.26E-04	0.90	3.59E+01	1.91E+01
20	1	324	1.645	0.852	0.118	0.021	1.20E-03	1.29E-03	0.92	6.57E+01	3.41E+01
20	1	318	1.906	0.931	0.135	0.023	1.39E-03	1.41E-03	0.98	7.62E+01	3.72E+01
20	1	312	3.363	1.812	0.253	0.044	2.45E-03	2.75E-03	0.89	1.34E+02	7.24E+01
20	1	306	3.85	1.828	0.285	0.044	2.80E-03	2.78E-03	1.01	1.54E+02	7.31E+01
20	1	300	2.63	1.298	0.202	0.031	1.91E-03	1.97E-03	0.97	1.05E+02	5.19E+01
20	1	294	1.532	0.957	0.118	0.023	1.11E-03	1.45E-03	0.77	6.12E+01	3.82E+01
20	1	288	1.093	0.592	0.082	0.014	7.95E-04	9.00E-04	0.88	4.37E+01	2.37E+01
20	1	282	0.34	0.182	0.024	0.004	2.47E-04	2.77E-04	0.89	1.36E+01	7.27E+00
20	1	270	0.036	0.027	0.004	0.001	2.62E-05	4.10E-05	0.64	1.44E+00	1.08E+00

Table A.5. Data from bubblers at 20, 40, and 70 m downwind

Downwind distance (m)	Height (m)	Angle (degrees)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	2	330	1.253	0.682	0.093	0.017	9.12E-04	1.04E-03	0.88	5.01E+01	2.73E+01
20	2	324	1.916	1.039	0.147	0.025	1.39E-03	1.58E-03	0.88	7.66E+01	4.15E+01
20	2	318	2.132	1.276	0.163	0.031	1.55E-03	1.94E-03	0.80	8.52E+01	5.10E+01
20	2	312	2.025	1.256	0.151	0.03	1.47E-03	1.91E-03	0.77	8.09E+01	5.02E+01
20	2	306	2.76	1.37	0.214	0.033	2.01E-03	2.08E-03	0.96	1.10E+02	5.48E+01
20	2	300	2.807	1.4	0.198	0.034	2.04E-03	2.13E-03	0.96	1.12E+02	5.60E+01
20	2	294	2.095	1.088	0.152	0.026	1.52E-03	1.65E-03	0.92	8.37E+01	4.35E+01
20	2	288	1.012	0.56	0.074	0.014	7.37E-04	8.51E-04	0.87	4.04E+01	2.24E+01
40	0	336	0.627	0.346	0.045	0.008	4.56E-04	5.26E-04	0.87	2.51E+01	1.38E+01
40	0	324	0.82	0.438	0.06	0.011	5.97E-04	6.66E-04	0.90	3.28E+01	1.75E+01
40	0	312	1.0	0.611	0.07	0.015	7.28E-04	9.28E-04	0.78	4.00E+01	2.44E+01
40	0	300	1.287	0.68	0.094	0.016	9.37E-04	1.03E-03	0.91	5.14E+01	2.72E+01
40	0	288	0.28	0.19	0.02	0.005	2.04E-04	2.89E-04	0.71	1.12E+01	7.59E+00
70	0	324	0.323	0.141	0.025	0.003	2.35E-04	2.14E-04	1.10	1.29E+01	5.64E+00
70	0	312	0.509	0.259	0.039	0.006	3.70E-04	3.94E-04	0.94	2.03E+01	1.04E+01
70	0	300	0.662	0.359	0.05	0.009	4.82E-04	5.45E-04	0.88	2.65E+01	1.43E+01

Appendix B

DATA FROM FILTERS

Table B.1. Data from filters at 40 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Air flow (l/s)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	1	360	1.64	0.719	0.387	0.072	0.009	8.87E-06	9.97E-06	0.89	4.87E-01	2.62E-01
40	1	354	0.904	2.757	1.802	0.276	0.044	6.17E-05	8.42E-05	0.73	3.39E+00	2.21E+00
40	1	348	0.997	10.595	5.644	1.06	0.137	2.15E-04	2.39E-04	0.90	1.18E+01	6.29E+00
40	1	342	0.854	14.321	8.2	1.432	0.198	3.39E-04	4.06E-04	0.84	1.86E+01	1.07E+01
40	1	336	1.03	20.078	11.556	2.008	0.28	3.94E-04	4.74E-04	0.83	2.17E+01	1.25E+01
40	1	330	0.845	22.035	11.556	2.204	0.28	5.28E-04	5.78E-04	0.91	2.90E+01	1.52E+01
40	1	324	0.908	29.034	14.978	2.903	0.362	6.47E-04	6.97E-04	0.93	3.55E+01	1.83E+01
40	1	318	0.658	28.805	14.978	2.881	0.362	8.86E-04	9.62E-04	0.92	4.86E+01	2.53E+01
40	1	312	1.13	37.628	19.222	3.763	0.465	6.74E-04	7.19E-04	0.94	3.70E+01	1.89E+01
40	1	306	0.808	44.526	24.889	4.453	0.602	1.11E-03	1.30E-03	0.86	6.12E+01	3.42E+01
40	1	294	0.765	26.987	14.311	2.699	0.346	7.14E-04	7.90E-04	0.90	3.92E+01	2.08E+01
40	1	282	1.18	2.68	1.371	0.268	0.033	4.60E-05	4.91E-05	0.94	2.52E+00	1.29E+00
40	1	276	1.08	1.371	0.771	0.137	0.019	2.57E-05	3.02E-05	0.85	1.41E+00	7.93E-01
40	1	270	0.921	0.454	0.227	0.045	0.005	9.97E-06	1.04E-05	0.96	5.48E-01	2.74E-01
40	2	324	0.420	19.95	10.36	1.995	0.251	9.61E-04	1.04E-03	0.92	5.28E+01	2.74E+01
40	2	300	0.9	47.098	24	4.71	0.581	1.06E-03	1.13E-03	0.94	5.81E+01	2.96E+01

Table B.2. Data from filters at 70 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Air flow (l/s)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
70	1	354	0.726	0.39	0.193	0.039	0.005	1.09E-05	1.12E-05	0.97	5.97E-01	2.95E-01
70	1	348	1.2	3.816	1.955	0.382	0.047	6.43E-05	6.88E-05	0.93	3.53E+00	1.81E+00
70	1	342	0.872	8.192	3.978	0.819	0.096	1.90E-04	1.93E-04	0.99	1.04E+01	5.07E+00
70	1	336	0.862	7.713	3.688	0.771	0.089	1.81E-04	1.81E-04	1.00	9.94E+00	4.75E+00
70	1	330	0.637	5.014	2.8	0.501	0.068	1.59E-04	1.86E-04	0.86	8.75E+00	4.88E+00
70	1	324	1.03	12.488	6.0	1.249	0.145	2.45E-04	2.46E-04	1.00	1.35E+01	6.47E+00
70	1	318	1.03	15.155	7.156	1.516	0.173	2.98E-04	2.93E-04	1.01	1.63E+01	7.72E+00
70	1	312	0.64	7.617	4.044	0.762	0.098	2.41E-04	2.67E-04	0.90	1.32E+01	7.02E+00
70	1	306	0.94	22.931	11.788	2.293	0.285	4.94E-04	5.30E-04	0.93	2.71E+01	1.39E+01
70	1	300	0.629	14.588	7.666	1.459	0.186	4.69E-04	5.15E-04	0.91	2.58E+01	1.35E+01
70	1	288	1.04	3.315	1.756	0.332	0.042	6.45E-05	7.13E-05	0.90	3.54E+00	1.88E+00
70	1	282	0.987	1.195	0.578	0.12	0.014	2.45E-05	2.47E-05	0.99	1.35E+00	6.51E-01
70	1	276	1.02	0.543	0.264	0.054	0.006	1.08E-05	1.09E-05	0.99	5.92E-01	2.88E-01
70	2	324	0.927	11.173	5.644	1.117	0.137	2.44E-04	2.57E-04	0.95	1.34E+01	6.76E+00
70	2	312	0.944	18.528	902	1.853	0.223	3.97E-04	4.12E-04	0.96	2.18E+01	1.08E+01
70	2	300	0.808	16.044	10.644	1.604	0.258	4.02E-04	5.56E-04	0.72	2.21E+01	1.46E+01

Table B.3. Data from filters at 100 m downwind and 1 m height

Downwind distance (m)	Height (m)	Angle (deg)	Air flow (l/s)	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
100	1	354	1.28	0.2	0.111	0.02	0.003	3.16E-06	3.66E-06	0.86	1.74E-01	9.64E-02
100	1	348	0.889	1.325	0.682	0.133	0.017	3.02E-05	3.24E-05	0.93	1.66E+00	8.52E-01
100	1	342	0.836	4.177	2.08	0.418	0.05	1.01E-04	1.05E-04	0.96	5.55E+00	2.76E+00
100	1	336	1.01	4.559	2.222	0.456	0.054	9.13E-05	9.29E-05	0.98	5.02E+00	2.44E+00
100	1	330	0.858	3.956	2.171	0.396	0.053	9.33E-05	1.07E-04	0.87	5.12E+00	2.81E+00
100	1	324	0.945	4.912	2.244	0.491	0.054	1.05E-04	1.00E-04	1.05	5.78E+00	2.64E+00
100	1	312	0.15	1.733	1.078	0.173	0.026	2.34E-04	3.04E-04	0.77	1.28E+01	7.99E+00
100	1	306	1.0	14.528	7.178	1.453	0.174	2.94E-04	3.03E-04	0.97	1.61E+01	7.98E+00
100	1	300	0.442	5.453	2.689	0.545	0.065	2.50E-04	2.57E-04	0.97	1.37E+01	6.76E+00
100	1	294	1.01	3.641	1.704	0.364	0.041	7.29E-05	7.13E-05	1.02	4.01E+00	1.87E+00
100	1	288	1.39	1.494	0.764	0.149	0.018	2.17E-05	2.32E-05	0.94	1.19E+00	6.11E-01
100	1	282	0.807	0.794	0.42	0.079	0.01	1.99E-05	2.20E-05	0.91	1.09E+00	5.78E-01
100	1	276	0.889	0.136	0.072	0.014	0.002	3.10E-06	3.42E-06	0.90	1.70E-01	9.00E-02

Table B.4. Data from filters at 20 and 200 m downwind and 1 m height

Downwind distance (m)	Height (m)	Angle (deg)	Air flow (l/s)	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	1	348	1.05	20.898	10.65	2.09	0.258	4.03E-04	4.28E-04	0.94	2.21E+01	1.13E+01
20	1	276	1.04	4.29	2.18	0.429	0.053	8.35E-05	8.85E-05	0.94	4.58E+00	2.33E+00
200	1	354	1.12	0.001	0.005	0.001	0	1.81E-08	1.89E-07	0.10	9.92E-04	4.96E-03
200	1	336	0.975	1.472	0.611	0.147	0.015	3.05E-05	2.65E-05	1.15	1.68E+00	6.96E-01
200	1	330	1.01	1.146	0.537	0.115	0.013	2.30E-05	2.25E-05	1.02	1.26E+00	5.91E-01
200	1	324	0.52	0.854	0.402	0.085	0.01	3.32E-05	3.27E-05	1.02	1.82E+00	8.59E-01
200	1	318	0.753	1.187	0.564	0.119	0.014	3.19E-05	3.16E-05	1.01	1.75E+00	8.32E-01
200	1	312	0.635	1.265	0.578	0.127	0.014	4.03E-05	3.84E-05	1.05	2.21E+00	1.01E+00
200	1	306	0.925	4.079	1.782	0.408	0.043	8.92E-05	8.14E-05	1.10	4.90E+00	2.14E+00
200	1	300	0.381	1.074	0.553	0.107	0.013	5.70E-05	6.13E-05	0.93	3.13E+00	1.61E+00
200	1	294	0.885	0.997	0.458	0.1	0.011	2.28E-05	2.19E-05	1.04	1.25E+00	5.75E-01
200	1	288	1.11	0.471	0.224	0.047	0.005	8.59E-06	8.52E-06	1.01	4.71E-01	2.24E-01
200	1	276	1.4	0.009	0.013	0.001	0	1.30E-07	3.92E-07	0.33	7.14E-03	1.03E-02

Appendix C

DATA FROM SEQUENTIALS

Table C.1. Data from sequentials at 20 m downwind, 337.5° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	1	337.5	0	3.746	2.023	0.375	0.049	8.27E-04	9.32E-04	0.89	4.54E+01	2.45E+01
20	1	337.5	1	1.442	0.981	0.144	0.024	1.59E-03	2.26E-03	0.70	8.74E+01	5.95E+01
20	1	337.5	2	0.473	0.33	0.047	0.008	5.22E-04	7.60E-04	0.69	2.87E+01	2.00E+01
20	1	337.5	3	0.019	0.019	0.003	0	2.10E-05	4.38E-05	0.48	1.15E+00	1.15E+00
20	1	337.5	4	0.044	0.026	0.007	0.001	4.86E-05	5.99E-05	0.81	2.67E+00	1.58E+00
20	1	337.5	5	0.654	0.339	0.065	0.008	7.22E-04	7.81E-04	0.92	3.96E+01	2.05E+01
20	1	337.5	6	0.267	0.149	0.027	0.004	2.95E-04	3.43E-04	0.86	1.62E+01	9.03E+00
20	1	337.5	7	0.001	0.006	0.001	0	1.10E-06	1.38E-05	0.08	6.06E-02	3.64E-01
20	3	337.5	0	5.878	3.769	0.588	0.091	1.30E-03	1.74E-03	0.75	7.12E+01	4.57E+01
20	3	337.5	1	3.749	2.117	0.375	0.051	4.14E-03	4.88E-03	0.85	2.27E+02	1.28E+02
20	3	337.5	2	1.031	0.612	0.103	0.015	1.14E-03	1.41E-03	0.81	6.25E+01	3.71E+01
20	3	337.5	3	0.035	0.04	0.006	0.001	3.86E-05	9.22E-05	0.42	2.12E+00	2.42E+00
20	3	337.5	4	0.038	0.027	0.006	0.001	4.19E-05	6.22E-05	0.67	2.30E+00	1.64E+00
20	3	337.5	5	0.711	0.383	0.071	0.009	7.85E-04	8.82E-04	0.89	4.31E+01	2.32E+01
20	3	337.5	6	0.184	0.123	0.018	0.003	2.03E-04	2.83E-04	0.72	1.12E+01	7.45E+00
20	3	337.5	7	0.019	0.078	0.003	0.002	2.10E-05	1.80E-04	0.12	1.15E+00	4.73E+00

Table C.2. Data from sequentials at 20 m downwind, 315° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	1	315	0	11.121	6.102	1.112	0.148	2.45E-03	2.81E-03	0.87	1.35E+02	7.40E+01
20	1	315	1	0.367	0.186	0.037	0.004	4.05E-04	4.29E-04	0.95	2.22E+01	1.13E+01
20	1	315	2	1.677	0.901	0.168	0.022	1.85E-03	2.08E-03	0.89	1.02E+02	5.46E+01
20	1	315	3	1.688	0.894	0.169	0.022	1.86E-03	2.06E-03	0.90	1.02E+02	5.42E+01
20	1	315	4	2.618	1.446	0.262	0.035	2.89E-03	3.33E-03	0.87	1.59E+02	8.76E+01
20	1	315	5	2.695	1.57	0.27	0.038	2.97E-03	3.62E-03	0.82	1.63E+02	9.52E+01
20	1	315	6	0.154	0.097	0.015	0.002	1.70E-04	2.23E-04	0.76	9.33E+00	5.88E+00
20	1	315	7	0.109	0.071	0.011	0.002	1.20E-04	1.64E-04	0.74	6.61E+00	4.30E+00
20	3	315	0	9.417	5.302	0.942	0.128	2.08E-03	2.44E-03	0.85	1.14E+02	6.43E+01
20	3	315	1	0.44	0.243	0.044	0.006	4.86E-04	5.60E-04	0.87	2.67E+01	1.47E+01
20	3	315	2	1.623	0.868	0.162	0.021	1.79E-03	2.00E-03	0.90	9.84E+01	5.26E+01
20	3	315	3	1.835	0.986	0.184	0.024	2.03E-03	2.27E-03	0.89	1.11E+02	5.98E+01
20	3	315	4	1.499	0.812	0.15	0.02	1.65E-03	1.87E-03	0.88	9.08E+01	4.92E+01
20	3	315	5	1.877	1.07	0.188	0.026	2.07E-03	2.47E-03	0.84	1.14E+02	6.48E+01
20	3	315	6	0.098	0.079	0.016	0.002	1.08E-04	1.82E-04	0.59	5.94E+00	4.79E+00
20	3	315	7	0.159	0.086	0.016	0.002	1.75E-04	1.98E-04	0.89	9.64E+00	5.21E+00

Table C.3. Data from sequentials at 20 m downwind, 337.5° and 315° azimuths, and 6 m height

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	6	337.5	0	1.914	1.048	0.191	0.025	4.22E-04	4.83E-04	0.87	2.32E+01	1.27E+01
20	6	337.5	1	0.004	0.009	0.001	0.000	4.41E-06	2.07E-05	0.21	2.42E-01	5.45E-01
20	6	337.5	2	1.094	0.514	0.109	0.012	1.21E-03	1.18E-03	1.02	6.63E+01	3.12E+01
20	6	337.5	3	0.307	0.176	0.031	0.004	3.39E-04	4.06E-04	0.84	1.86E+01	1.07E+01
20	6	337.5	4	0.281	0.136	0.028	0.003	3.10E-04	3.13E-04	0.99	1.70E+01	8.24E+00
20	6	337.5	5	0.145	0.098	0.015	0.002	1.60E-04	2.26E-04	0.71	8.79E+00	5.94E+00
20	6	337.5	6	0.115	0.073	0.012	0.002	1.27E-04	1.68E-04	0.75	6.97E+00	4.42E+00
20	6	337.5	7	0.003	0.007	0.001	0.000	3.31E-06	1.61E-05	0.21	1.82E-01	4.24E-01
20	6	315	0	2.455	1.5	0.246	0.036	5.42E-04	6.91E-04	0.78	2.98E+01	1.82E+01
20	6	315	1	0.081	0.048	0.013	0.001	8.94E-05	1.11E-04	0.81	4.91E+00	2.91E+00
20	6	315	2	0.91	0.507	0.091	0.012	1.00E-03	1.17E-03	0.86	5.52E+01	3.07E+01
20	6	315	3	0.558	0.34	0.056	0.008	6.16E-04	7.83E-04	0.79	3.38E+01	2.06E+01
20	6	315	4	0.422	0.214	0.042	0.005	4.66E-04	4.93E-04	0.94	2.56E+01	1.30E+01
20	6	315	5	0.56	0.262	0.056	0.006	6.18E-04	6.04E-04	1.02	3.39E+01	1.59E+01
20	6	315	6	0.018	0.023	0.003	0.001	1.99E-05	5.30E-05	0.37	1.09E+00	1.39E+00
20	6	315	7	0.019	0.014	0.003	0	2.10E-05	3.23E-05	0.65	1.15E+00	8.48E-01

Table C.4. Data from sequentials at 20 m downwind, 292.5° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	1	292.5	0	6.978	3.844	0.698	0.093	1.54E-03	1.77E-03	0.87	8.46E+01	4.66E+01
20	1	292.5	1	0.006	0.012	0.001	0	6.62E-06	2.76E-05	0.24	3.64E-01	7.27E-01
20	1	292.5	2	0.73	0.387	0.073	0.009	8.06E-04	8.92E-04	0.90	4.42E+01	2.35E+01
20	1	292.5	3	2.698	1.527	0.27	0.037	2.98E-03	3.52E-03	0.85	1.64E+02	9.25E+01
20	1	292.5	4	1.663	0.931	0.166	0.023	1.84E-03	2.15E-03	0.86	1.01E+02	5.64E+01
20	1	292.5	5	0.971	0.178	0.097	0.004	1.07E-03	4.10E-04	2.61	5.88E+01	1.08E+01
20	1	292.5	6	0.007	0.149	0.001	0.004	7.73E-06	3.43E-04	0.02	4.24E-01	9.03E+00
20	1	292.5	7	0.002	0.093	0	0.002	2.21E-06	2.14E-04	0.01	1.21E-01	5.64E+00
20	3	292.5	0	6.728	3.356	0.673	0.081	1.48E-03	1.55E-03	0.96	8.16E+01	4.07E+01
20	3	292.5	1	0.012	0.007	0.002	0	1.32E-05	1.61E-05	0.82	7.27E-01	4.24E-01
20	3	292.5	2	0.603	0.258	0.06	0.006	6.65E-04	5.94E-04	1.12	3.65E+01	1.56E+01
20	3	292.5	3	2.463	1.26	0.246	0.031	2.72E-03	2.90E-03	0.94	1.49E+02	7.64E+01
20	3	292.5	4	2.133	1.084	0.213	0.026	2.35E-03	2.50E-03	0.94	1.29E+02	6.57E+01
20	3	292.5	5	1.443	0.709	0.144	0.017	1.59E-03	1.63E-03	0.97	8.75E+01	4.30E+01
20	3	292.5	6	0.004	0.021	0.001	0.001	4.41E-06	4.84E-05	0.09	2.42E-01	1.27E+00
20	3	292.5	7	0.007	0.153	0.001	0.004	7.73E-06	3.53E-04	0.02	4.24E-01	9.27E+00

Table C.5. Data from sequentials at 40 m downwind, 337.5° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	1	337.5	0	2.436	1.167	0.244	0.028	5.38E-04	5.38E-04	1.00	2.95E+01	1.41E+01
40	1	337.5	1	1.479	0.691	0.148	0.017	1.63E-03	1.59E-03	1.03	8.96E+01	4.19E+01
40	1	337.5	2	0.264	0.134	0.026	0.003	2.91E-04	3.09E-04	0.94	1.60E+01	8.12E+00
40	1	337.5	3	0.003	0.267	0.001	0.006	3.31E-06	6.15E-04	0.01	1.82E-01	1.62E+01
40	1	337.5	4	0.007	0.007	0.001	0	7.73E-06	1.61E-05	0.48	4.24E-01	4.24E-01
40	1	337.5	5	0.299	0.141	0.03	0.003	3.30E-04	3.25E-04	1.02	1.81E+01	8.55E+00
40	1	337.5	6	0.216	0.106	0.022	0.003	2.38E-04	2.44E-04	0.98	1.31E+01	6.42E+00
40	1	337.5	7	0.007	0.011	0.001	0	7.73E-06	2.53E-05	0.30	4.24E-01	6.67E-01
40	3	337.5	0	2.123	0.984	0.212	0.024	4.69E-04	4.53E-04	1.03	2.57E+01	1.19E+01
40	3	337.5	1	1.214	0.584	0.121	0.014	1.34E-03	1.35E-03	1.00	7.36E+01	3.54E+01
40	3	337.5	2	0.224	0.122	0.022	0.003	2.47E-04	2.81E-04	0.88	1.36E+01	7.39E+00
40	3	337.5	3	0.01	0.013	0.002	0	1.10E-05	3.00E-05	0.37	6.06E-01	7.88E-01
40	3	337.5	4	0.01	0.009	0.002	0	1.10E-05	2.07E-05	0.53	6.06E-01	5.45E-01
40	3	337.5	5	0.279	0.137	0.028	0.003	3.08E-04	3.16E-04	0.98	1.69E+01	8.30E+00
40	3	337.5	6	0.128	0.069	0.013	0.002	1.41E-04	1.59E-04	0.89	7.76E+00	4.18E+00
40	3	337.5	7	0.017	0.017	0.003	0	1.88E-05	3.92E-05	0.48	1.03E+00	1.03E+00

Table C.6. Data from sequentials at 20 m downwind, 292.5° azimuth, and 6 m and at 40 m downwind, 337.5° azimuth, and 8 m

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	6	292.5	0	1.731	0.889	0.017	0.025	3.82E-04	4.10E-04	0.93	2.10E+01	1.08E+01
20	6	292.5	1	0.001	0.006	0	0	1.10E-06	1.38E-05	0.08	6.06E-02	3.64E-01
20	6	292.5	2	0.173	0.063	0.017	0.002	1.91E-04	1.45E-04	1.32	1.05E+01	3.82E+00
20	6	292.5	3	0.63	0.356	0.063	0.009	6.95E-04	8.20E-04	0.85	3.82E+01	2.16E+01
20	6	292.5	4	0.654	0.338	0.065	0.008	7.22E-04	7.79E-04	0.93	3.96E+01	2.05E+01
20	6	292.5	5	0.331	0.174	0.033	0.004	3.65E-04	4.01E-04	0.91	2.01E+01	1.05E+01
20	6	292.5	6	0.001	0.008	0	0	1.10E-06	1.84E-05	0.06	6.06E-02	4.85E-01
20	6	292.5	7	0.002	0.003	0	0	2.21E-06	6.91E-06	0.32	1.21E-01	1.82E-01
40	8	337.5	0	0.49	0.227	0.049	0.005	1.08E-04	1.05E-04	1.03	5.94E+00	2.75E+00
40	8	337.5	1	0.106	0.05	0.011	0.001	1.17E-04	1.15E-04	1.02	6.42E+00	3.03E+00
40	8	337.5	2	0.108	0.051	0.011	0.001	1.19E-04	1.18E-04	1.01	6.55E+00	3.09E+00
40	8	337.5	3	0.022	0.014	0.004	0	2.43E-05	3.23E-05	0.75	1.33E+00	8.48E-01
40	8	337.5	4	0.027	0.016	0.004	0	2.98E-05	3.69E-05	0.81	1.64E+00	9.70E-01
40	8	337.5	5	0.093	0.042	0.015	0.001	1.03E-04	9.68E-05	1.06	5.64E+00	2.55E+00
40	8	337.5	6	0.041	0.021	0.007	0.001	4.52E-05	4.84E-05	0.94	2.48E+00	1.27E+00
40	8	337.5	7	0.035	0.018	0.006	0	3.86E-05	4.15E-05	0.93	2.12E+00	1.09E+00

Table C.7. Data from sequentials at 40 m downwind, 315° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m^3)		U/F mole ratio	Concentration (mg/m^3)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	1	315	0	4.744	2.16	0.474	0.052	1.05E-03	9.95E-04	1.05	5.75E+01	2.62E+01
40	1	315	1	0.28	0.177	0.028	0.004	3.09E-04	4.08E-04	0.76	1.70E+01	1.07E+01
40	1	315	2	0.932	0.431	0.093	0.01	1.03E-03	9.93E-04	1.04	5.65E+01	2.61E+01
40	1	315	3	0.731	0.34	0.073	0.008	8.07E-04	7.83E-04	1.03	4.43E+01	2.06E+01
40	1	315	4	0.846	0.32	0.085	0.008	9.34E-04	7.37E-04	1.27	5.13E+01	1.94E+01
40	1	315	5	0.901	0.387	0.09	0.009	9.94E-04	8.92E-04	1.12	5.46E+01	2.35E+01
40	1	315	6	0.187	0.087	0.019	0.002	2.06E-04	2.00E-04	1.03	1.13E+01	5.27E+00
40	1	315	7	0.148	0.123	0.015	0.003	1.63E-04	2.83E-04	0.58	8.97E+00	7.45E+00
40	3	315	0	3.523	1.791	0.352	0.043	7.78E-04	8.25E-04	0.94	4.27E+01	2.17E+01
40	3	315	1	0.169	0.079	0.017	0.002	1.87E-04	1.82E-04	1.02	1.02E+01	4.79E+00
40	3	315	2	0.509	0.287	0.051	0.007	5.62E-04	6.61E-04	0.85	3.08E+01	1.74E+01
40	3	315	3	1.2	0.68	0.12	0.016	1.32E-03	1.57E-03	0.85	7.27E+01	4.12E+01
40	3	315	4	0.577	0.287	0.058	0.007	6.37E-04	6.61E-04	0.96	3.50E+01	1.74E+01
40	3	315	5	0.849	0.393	0.085	0.01	9.37E-04	9.05E-04	1.03	5.15E+01	2.38E+01
40	3	315	6	0.002	0.012	0	0	2.21E-06	2.76E-05	0.08	1.21E-01	7.27E-01
40	3	315	7		0.008		0	0	1.84E-05	0	0	4.85E-01

Table C.8. Data from sequentials at 40 m downwind, 315° azimuth, and 8 and 15 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	8	315	0	1.385	0.673	0.139	0.016	3.06E-04	3.10E-04	0.99	1.68E+01	8.16E+00
40	8	315	1	0.031	0.017	0.005	0	3.42E-05	3.92E-05	0.87	1.88E+00	1.03E+00
40	8	315	2	0.443	0.2	0.044	0.005	4.89E-04	4.61E-04	1.06	2.68E+01	1.21E+01
40	8	315	3	0.256	0.123	0.026	0.003	2.83E-04	2.83E-04	1.00	1.55E+01	7.45E+00
40	8	315	4	0.046	0.03	0.007	0.001	5.08E-05	6.91E-05	0.73	2.79E+00	1.82E+00
40	8	315	5	0.272	0.119	0.027	0.003	3.00E-04	2.74E-04	1.09	1.65E+01	7.21E+00
40	8	315	6	0.007	0.007	0.001	0	7.73E-06	1.61E-05	0.48	4.24E-01	4.24E-01
40	8	315	7	0.005	0.004	0.001	0	5.52E-06	9.22E-06	0.60	3.03E-01	2.42E-01
40	15	315	0	0.018	0.008	0.003	0	3.97E-06	3.69E-06	1.08	2.18E-01	9.70E-02
40	15	315	1	0.003	0.001	0.001	0	3.31E-06	2.30E-06	1.44	1.82E-01	6.06E-02
40	15	315	2	0.002	0.002	0	0	2.21E-06	4.61E-06	0.48	1.21E-01	1.21E-01
40	15	315	3	0.004	0.001	0.001	0	4.41E-06	2.30E-06	1.92	2.42E-01	6.06E-02
40	15	315	4	0.003	0.002	0.001	0	3.31E-06	4.61E-06	0.72	1.82E-01	1.21E-01
40	15	315	5	0.004	0.002	0.001	0	4.41E-06	4.61E-06	0.96	2.42E-01	1.21E-01
40	15	315	6	0.004	0.001	0.001	0	4.41E-06	2.30E-06	1.92	2.42E-01	6.06E-02
40	15	315	7	0.003	0.002	0.001	0	3.31E-06	4.61E-06	0.72	1.82E-01	1.21E-01

Table C.9. Data from sequentials at 40 m downwind, 292.5° azimuth, and 1 and 3 m heights

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	1	292.5	0	2.35	1.298	0.235	0.031	5.19E-04	5.98E-04	0.87	2.85E+01	1.57E+01
40	1	292.5	1	0.024	0.016	0.004	0	2.65E-05	3.69E-05	0.72	1.45E+00	9.70E-01
40	1	292.5	2	0.113	0.073	0.011	0.002	1.25E-04	1.68E-04	0.74	6.85E+00	4.42E+00
40	1	292.5	3	0.824	0.046	0.082	0.001	9.09E-04	1.06E-04	8.58	4.99E+01	2.79E+00
40	1	292.5	4	0.658	0.039	0.066	0.001	7.26E-04	8.99E-05	8.08	3.99E+01	2.36E+00
40	1	292.5	5	0.437	0.027	0.044	0.001	4.82E-04	6.22E-05	7.75	2.65E+01	1.64E+00
40	1	292.5	6	0.024	0.026	0.004	0.001	2.65E-05	5.99E-05	0.44	1.45E+00	1.58E+00
40	1	292.5	7	0.018	0.021	0.003	0.001	1.99E-05	4.84E-05	0.41	1.09E+00	1.27E+00
40	3	292.5	0	2.324	1.069	0.232	0.026	5.13E-04	4.93E-04	1.04	2.82E+01	1.30E+01
40	3	292.5	1	0.028	0.006	0.004	0	3.09E-05	1.38E-05	2.24	1.70E+00	3.64E-01
40	3	292.5	2	0.157	0.059	0.016	0.001	1.73E-04	1.36E-04	1.27	9.52E+00	3.58E+00
40	3	292.5	3	0.87	0.373	0.087	0.009	9.60E-04	8.59E-04	1.12	5.27E+01	2.26E+01
40	3	292.5	4	0.651	0.329	0.065	0.008	7.18E-04	7.58E-04	0.95	3.95E+01	1.99E+01
40	3	292.5	5	0.483	0.231	0.048	0.006	5.33E-04	5.32E-04	1.00	2.93E+01	1.40E+01
40	3	292.5	6	0.037	0.013	0.006	0	4.08E-05	3.00E-05	1.36	2.24E+00	7.88E-01
40	3	292.5	7	0.063	0.019	0.01	0	6.95E-05	4.38E-05	1.59	3.82E+00	1.15E+00

Table C.10. Data from sequentials at 40 m downwind, 292.5° azimuth, and 8 m height

Downwind distance (m)	Height (m)	Angle (deg)	Sequence number	Amount collected (mg)		Precision (mg)		C/q (sec/m³)		U/F mole ratio	Concentration (mg/m³)	
				Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	8	292.5	0	0.572	0.289	0.057	0.007	1.26E-04	1.33E-04	0.95	6.93E+00	3.50E+00
40	8	292.5	1	0.015	0.016	0.002	0	1.66E-05	3.69E-05	0.45	9.09E-01	9.70E-01
40	8	292.5	2	0.019	0.014	0.003	0	2.10E-05	3.23E-05	0.65	1.15E+00	8.48E-01
40	8	292.5	3	0.174	0.078	0.017	0.002	1.92E-04	1.80E-04	1.07	1.05E+01	4.73E+00
40	8	292.5	4	0.112	0.063	0.011	0.002	1.24E-04	1.45E-04	0.85	6.79E+00	3.82E+00
40	8	292.5	5	0.094	0.054	0.015	0.001	1.04E-04	1.24E-04	0.83	5.70E+00	3.27E+00
40	8	292.5	6	0.007	0.013	0.001	0	7.73E-06	3.00E-05	0.26	4.24E-01	7.88E-01
40	8	292.5	7	0.011	0.012	0.002	0	1.21E-05	2.76E-05	0.44	6.67E-01	7.27E-01

Appendix D

DATA FROM IMPACTORS AND SCOTCH PAPER

Table D.1. Data from impactors at 318° azimuth, 10 m downwind, and 2 m height and at 20 m downwind and 1 m height

Downwind distance (m)	Height (m)	Angle (deg)	Lower limit of particle size (μm)	Amount collected (mg)		Precision (mg)		U/F mole ratio
				Uranium	Fluorine	Uranium	Fluorine	
10	2	318	9.0	3.206	2.785	0.321	0.067	0.55
10	2	318	5.8	2.139	2.005	0.214	0.049	0.51
10	2	318	4.7	3.609	1.565	0.361	0.038	1.10
10	2	318	3.3	22.354	3.055	2.235	0.074	3.50
10	2	318	2.1	20.741	2.825	2.074	0.068	3.52
10	2	318	1.1	16.124	2.385	1.612	0.058	3.24
10	2	318	0.7	6.822	1.335	0.682	0.032	2.45
10	2	318	0.4	0.999	0.308	0.1	0.007	1.55
10	2	318	0	1.752	0.374	0.175	0.009	2.24
20	1	318	9.0	0.466	1.23	0.047	0.03	0.18
20	1	318	5.8	1.097	0.833	0.11	0.02	0.63
20	1	318	4.7	2.538	0.642	0.254	0.016	1.89
20	1	318	3.3	4.791	1.015	0.479	0.025	2.26
20	1	318	2.1	16.284	2.555	1.628	0.062	3.05
20	1	318	1.1	15.488	2.325	1.549	0.056	3.19
20	1	318	0.7	2.88	0.456	0.288	0.011	3.03
20	1	318	0.4	0.542	0.208	0.054	0.005	1.25
20	1	318	0	0.759	0.207	0.076	0.005	1.76

Table D.2. Data from impactors at 1 m height, 40 m downwind, and 318° azimuth and at 70 m downwind and 315° azimuth

Downwind distance (m)	Height (m)	Angle (deg)	Lower limit of particle size (μm)	Amount collected (mg)		Precision (mg)		U/F mole ratio
				Uranium	Fluorine	Uranium	Fluorine	
40	1	318	9	0.163	0.347	0.016	0.008	0.23
40	1	318	5.8	0.448	0.247	0.045	0.006	0.87
40	1	318	4.7	0.509	0.205	0.051	0.005	1.19
40	1	318	3.3	3.982	8.2	0.398	0.198	0.23
40	1	318	2.1	7.669	14.55	0.767	0.352	0.25
40	1	318	1.1	5.7	11.55	0.57	0.28	0.24
40	1	318	0.7	0.975	1.7	0.098	0.041	0.27
40	1	318	0.4	0.102	0.368	0.01	0.009	0.13
40	1	318	0	0.044	0.285	0.007	0.007	0.07
70	1	315	9	0.064	0.202	0.01	0.005	0.15
70	1	315	5.8	0.195	0.137	0.02	0.003	0.68
70	1	315	4.7	0.224	0.103	0.022	0.002	1.04
70	1	315	3.3	1.784	0.277	0.178	0.007	3.08
70	1	315	2.1	2.466	0.366	0.247	0.009	3.23
70	1	315	1.1	3.328	0.456	0.333	0.011	3.50
70	1	315	0.7	0.421	0.095	0.042	0.002	2.12
70	1	315	0.4	0.051	0.025	0.008	0.001	0.98
70	1	315	0	0.022	0.018	0.004	0	0.59

Table D.3. Data from impactors at 100 m downwind, 315° azimuth, and 1 m height

Downwind distance (m)	Height (m)	Angle (deg)	Lower limit of particle size (μm)	Amount collected (mg)		Precision (mg)		U/F mole ratio
				Uranium	Fluorine	Uranium	Fluorine	
100	1	315	9.0	0.056	0.087	0.009	0.002	0.31
100	1	315	5.8	0.156	0.065	0.016	0.002	1.15
100	1	315	4.7	0.185	0.051	0.019	0.001	1.74
100	1	315	3.3	0.605	0.118	0.061	0.003	2.46
100	1	315	2.1	1.838	0.261	0.184	0.006	3.37
100	1	315	1.1	1.492	0.226	0.149	0.005	3.16
100	1	315	0.7	0.073	0.03	0.012	0.001	1.17
100	1	315	0.4	0.108	0.025	0.011	0.001	2.07
100	1	315	0	0.003	0.066	0.001	0.002	0.02

Table D.4. Data from Scotch paper collectors

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)	Precision (mg)	Deposition (mg/m^2)	Deposition velocity (m/s)
10	2	318	7.8	0.78	31.2	1.26E-04
20	1	318	2.68	0.27	10.72	1.56E-04
40	1	318	1.61	0.16	6.44	1.47E-04
70	1	315	0.83	0.08	3.32	2.79E-04
100	1	315	0.42	0.04	1.68	1.45E-04

Appendix E

DATA FROM PETRI DISHES

Table E.1. Data from petri dishes on the ground at 10 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m²)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
10	0	354	0.118	0.031	0.012	0.001	8.027	2.109	1.82	6.03E-03	3.09E-03
10	0	348	0.419	0.078	0.042	0.002	28.503	5.306	2.57	1.52E-02	5.27E-03
10	0	342	1.038	0.306	0.104	0.007	70.612	20.816	1.62	5.53E-03	3.25E-03
10	0	336	0.741	0.217	0.074	0.005	50.408	14.762	1.64	1.15E-03	6.73E-04
10	0	330	1.505	0.202	0.151	0.005	102.381	13.741	3.57	1.29E-03	3.22E-04
10	0	324	1.13	0.241	0.113	0.006	76.871	16.395	2.25	9.83E-04	3.90E-04
10	0	318	1.474	0.338	0.147	0.008	100.272	22.993	2.09	7.85E-04	3.42E-04
10	0	312	1.699	0.353	0.17	0.009	115.578	24.014	2.31	6.75E-04	3.03E-04
10	0	306	1.298	0.27	0.13	0.007	88.299	18.367	2.30	4.24E-04	1.87E-04
10	0	300	1.015	0.218	0.102	0.005	69.048	14.830	2.23	4.67E-04	1.92E-04
10	0	294	0.49	0.141	0.049	0.003	33.333	9.592	1.66	2.02E-04	1.34E-04
10	0	288	0.235	0.081	0.024	0.002	15.986	5.510	1.39	1.43E-04	1.32E-04
10	0	282	0.092	0.039	0.015	0.001	6.259	2.653	1.13	1.39E-04	1.09E-04
10	0	276	0.049	0.03	0.008	0.001	3.333	2.041	0.78	1.16E-04	1.44E-04
10	0	270	0.023	0.023	0.004	0.001	1.565	1.565	0.48	1.22E-04	2.24E-04

Table E.2. Data from petri dishes on the ground at 20 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m^2)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
20	0	360	0.042	0.009	0.007	0	2.857	0.612	2.24	8.36E-04	3.09E-04
20	0	354	0.159	0.036	0.016	0.001	10.816	2.449	2.12		
20	0	348	0.29	0.074	0.029	0.002	19.728	5.034	1.88		
20	0	342	0.316	0.08	0.032	0.002	21.497	5.442	1.89	7.76E-04	3.85E-04
20	0	336	0.226	0.068	0.023	0.002	15.374	4.626	1.59	4.74E-04	2.40E-04
20	0	330	0.298	0.114	0.03	0.003	20.272	7.755	1.25	6.28E-04	4.51E-04
20	0	324	0.262	0.136	0.026	0.003	17.823	9.252	0.92	3.01E-04	3.02E-04
20	0	318	0.715	0.266	0.072	0.006	48.639	18.095	1.29	7.09E-04	5.40E-04
20	0	312	0.703	0.162	0.07	0.004	47.823	11.020	2.08	3.95E-04	1.69E-04
20	0	306	0.833	0.248	0.083	0.006	56.667	16.871	1.61	4.09E-04	2.57E-04
20	0	300	0.479	0.139	0.048	0.003	32.585	9.456	1.65	3.44E-04	2.03E-04
20	0	294	0.25	0.076	0.025	0.002	17.007	5.170	1.58	3.09E-04	1.50E-04
20	0	288	0.236	0.044	0.024	0.001	16.054	2.993	2.57	4.08E-04	1.41E-04
20	0	282	0.11	0.018	0.011	0	7.483	1.224	2.93	6.12E-04	1.87E-04
20	0	276	0.027	0.016	0.004	0	1.837	1.088	0.81		
20	0	270	0.017	0.017	0.003	0	1.156	1.156	0.48	8.93E-04	1.19E-03

Table E.3. Data from petri dishes on the ground at 40 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m^2)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
40	0	360	0.002	0.006	0.001	0	0.136	0.408	0.16	3.10E-04	1.73E-03
40	0	354	0.01	0.008	0.002	0	0.680	0.544	0.60	2.23E-04	2.73E-04
40	0	348	0.063	0.027	0.01	0.001	4.286	1.837	1.12	4.03E-04	3.24E-04
40	0	342	0.123	0.069	0.012	0.002	8.367	4.694	0.85	4.99E-04	4.89E-04
40	0	336	0.073	0.033	0.012	0.001	4.966	2.245	1.06	2.55E-04	2.00E-04
40[a]	0	330	0.089	0.08	0.014	0.002	6.054	5.442	0.53	2.32E-04	3.98E-04
40[a]	0	324	0.128	0.118	0.013	0.003	8.707	8.027	0.52	2.72E-04	4.87E-04
40[a]	0	318	0.119	0.115	0.012	0.003	8.095	7.823	0.50	1.85E-04	3.44E-04
40[a]	0	312	0.168	0.16	0.017	0.004	11.429	10.884	0.50	3.43E-04	6.40E-04
40[a]	0	306	0.215	0.176	0.022	0.004	14.626	11.973	0.59	2.65E-04	3.89E-04
40[a]	0	300	0.139	0.103	0.014	0.002	9.456	7.007	0.65		
40[a]	0	294	0.082	0.092	0.013	0.002	5.578	6.259	0.43	1.58E-04	3.35E-04
40[a]	0	288	0.025	0.032	0.004	0.001	1.701	2.177	0.37		
40[a]	0	282	0.007	0.013	0.001	0	0.476	0.884	0.26	2.10E-04	7.61E-04
40[a]	0	276	0.002	0.013	0	0	0.136	0.884	0.07	1.07E-04	1.24E-03
40	0	270	0.001	0.011	0	0	0.068	0.748	0.04	1.38E-04	3.04E-03

[a]Sand found in samples.

Table E.4. Data from petri dishes on the ground at 70 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m^2)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
70[a]	0	354	0.001	0.007	0	0	0.068	0.476	0.07	1.27E-04	1.79E-03
70[a]	0	348	0.012	0.011	0.002	0	0.816	0.748	0.52	2.57E-04	4.59E-04
70[a]	0	342	0.019	0.013	0.003	0	1.293	0.884	0.70	1.38E-04	1.94E-04
70[a]	0	336	0.023	0.03	0.004	0.001	1.565	2.041	0.37	1.75E-04	4.77E-04
70[a]	0	330	0.018	0.032	0.003	0.001	1.224	2.177	0.27	1.56E-04	4.95E-04
70[a]	0	324	0.027	0.022	0.004	0.001	1.837	1.497	0.59	1.51E-04	2.57E-04
70[a]	0	318	0.028	0.04	0.004	0.001	1.905	2.721	0.34	1.29E-04	3.92E-04
70[a]	0	312	0.028	0.035	0.004	0.001	1.905	2.381	0.38	1.60E-04	3.77E-04
70	0	306	0.084	0.024	0.013	0.001	5.714	1.633	1.68	2.34E-04	1.30E-04
70	0	300	0.062	0.016	0.01	0	4.218	1.088	1.86	1.82E-04	8.93E-05
70	0	294	0.024	0.008	0.004	0	1.633	0.544	1.44	?[b]	
70	0	288	0.016	0.007	0.003	0	1.088	0.476	1.09	3.41E-04	2.82E-04
70	0	282	0.007	0.005	0.001	0	0.476	0.340	0.67	3.93E-04	5.81E-04
70	0	276	0.002	0.003	0	0	0.136	0.204	0.32	2.56E-04	7.88E-04

[a]Sand found in samples.
[b] Value "?" reported in the Geisse report but no corresponding C/q value was available.

Table E.5 Data from petri dishes on the ground at 100 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m^2)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
100	0	348	0.002	0.001	0	0	0.136	0.068	0.96	9.13E-05	8.87E-05
100	0	342	0.008	0.002	0.001	0	0.544	0.136	1.92	1.09E-04	5.47E-05
100	0	336	0.01	0.003	0.002	0	0.680	0.204	1.60	1.51E-04	9.28E-05
100[a]	0	330	0.005	0.043	0.001	0.001	0.340	2.925	0.06	7.38E-05	1.16E-03
100[a]	0	324	0.01	0.034	0.002	0.001	0.680	2.313	0.14	1.31E-04	9.74E-04
100[a]	0	318	0.011	0.038	0.002	0.001	0.748	2.585	0.14		
100[a]	0	312	0.023	0.061	0.004	0.001	1.565	4.150	0.18	1.35E-04	5.77E-04
100[a]	0	306	0.029	0.068	0.005	0.002	1.973	4.626	0.20	1.36E-04	6.44E-04
100[a]	0	300	0.031	0.08	0.005	0.002	2.109	5.442	0.19	1.71E-04	8.95E-04
100[a]	0	294	0.006	0.026	0.001	0.001	0.408	1.769	0.11	1.13E-04	1.05E-03
100[a]	0	288	0.002	0.02	0	0	0.136	1.361	0.05	1.27E-04	2.48E-03
100[a]	0	282	0.003	0.01	0.001	0	0.204	0.680	0.14	2.07E-04	1.31E-03

[a]Sand found in samples.

Table E.6 Data from petri dishes on the ground at 200 m downwind

Downwind distance (m)	Height (m)	Angle (deg)	Amount collected (mg)		Precision (mg)		Deposition (mg/m^2)		U/F mole ratio	Deposition velocity (m/s)	
			Uranium	Fluorine	Uranium	Fluorine	Uranium	Fluorine		Uranium	Fluorine
200	0	336	0.002	0.002	0	0	0.136	0.136	0.48	9.01E-05	2.17E-04
200[a]	0	330	0.002	0.003	0	0	0.136	0.204	0.32	1.20E-04	3.84E-04
200[a]	0	324	0.003	0.003	0.001	0	0.204	0.204	0.48	1.24E-04	2.64E-04
200[a]	0	318	0.003	0.006	0.001	0	0.204	0.408	0.24	1.29E-04	5.45E-04
200[a]	0	312	0.004	0.003	0.001	0	0.272	0.204	0.64	1.37E-04	2.24E-04
200[a]	0	306	0.008	0.003	0.001	0	0.544	0.204	1.28	1.23E-04	1.06E-04
200[a]	0	300	0.007	0.004	0.001	0	0.476	0.272	0.84	1.69E-04	1.87E-04
200[a]	0	294	0.001	0.002	0.001	0	0.068	0.136	0.24	6.04E-05	2.63E-04
200[a]	0	288	0.001	0.006	0.001	0	0.068	0.408	0.08	1.60E-04	2.02E-03

[a] Sand found in samples.

Appendix F

TEMPERATURE DATA

a - plume
b - stretched wires
c - thermocouples

11–17 thermocouples per grid depending on distance to emission point

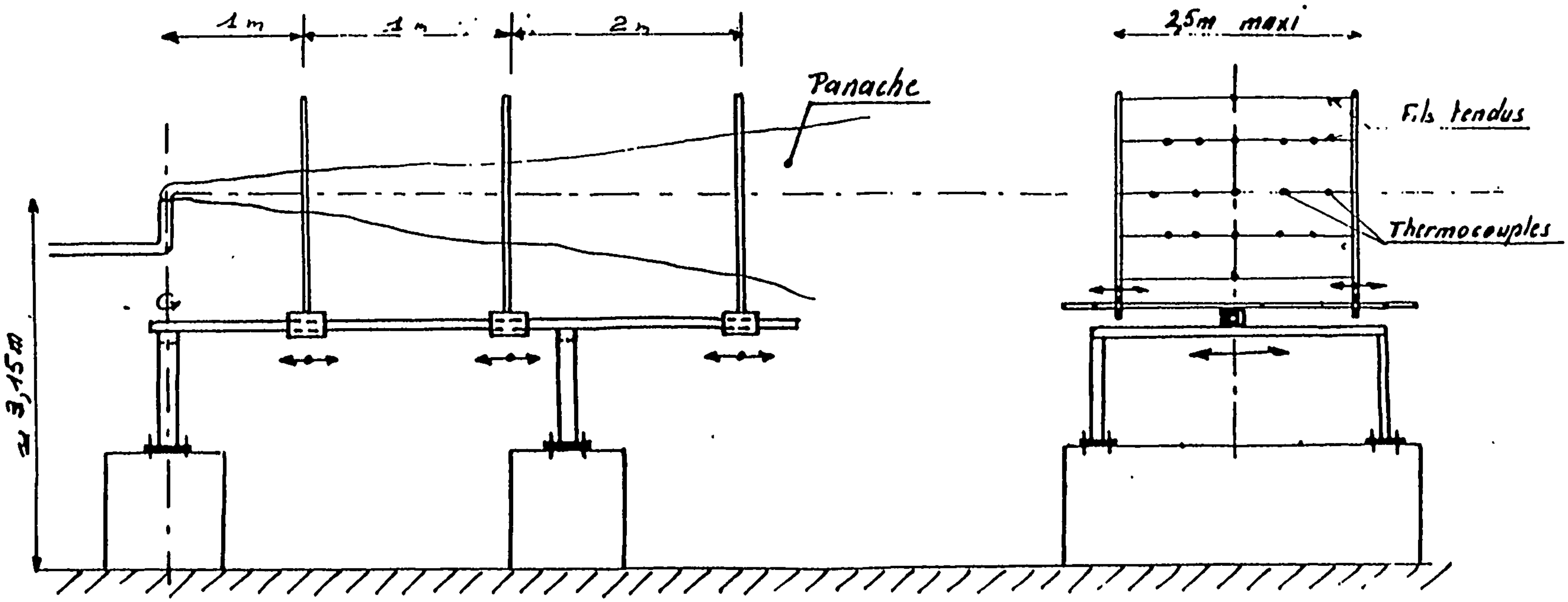
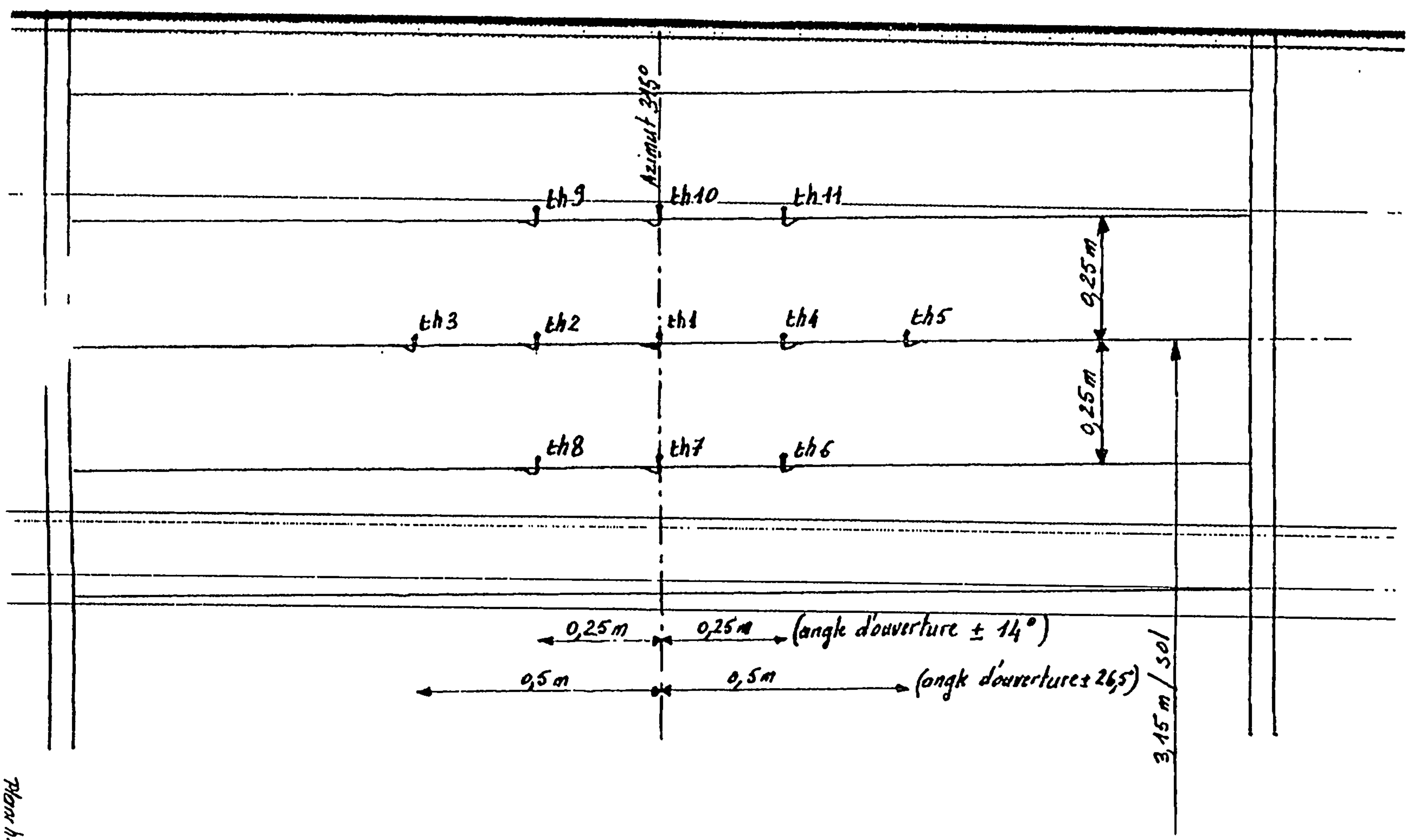


Fig. F.1. Temperature measurements.

a - angle of opening ∓14°
b - angle of opening ∓26.5°



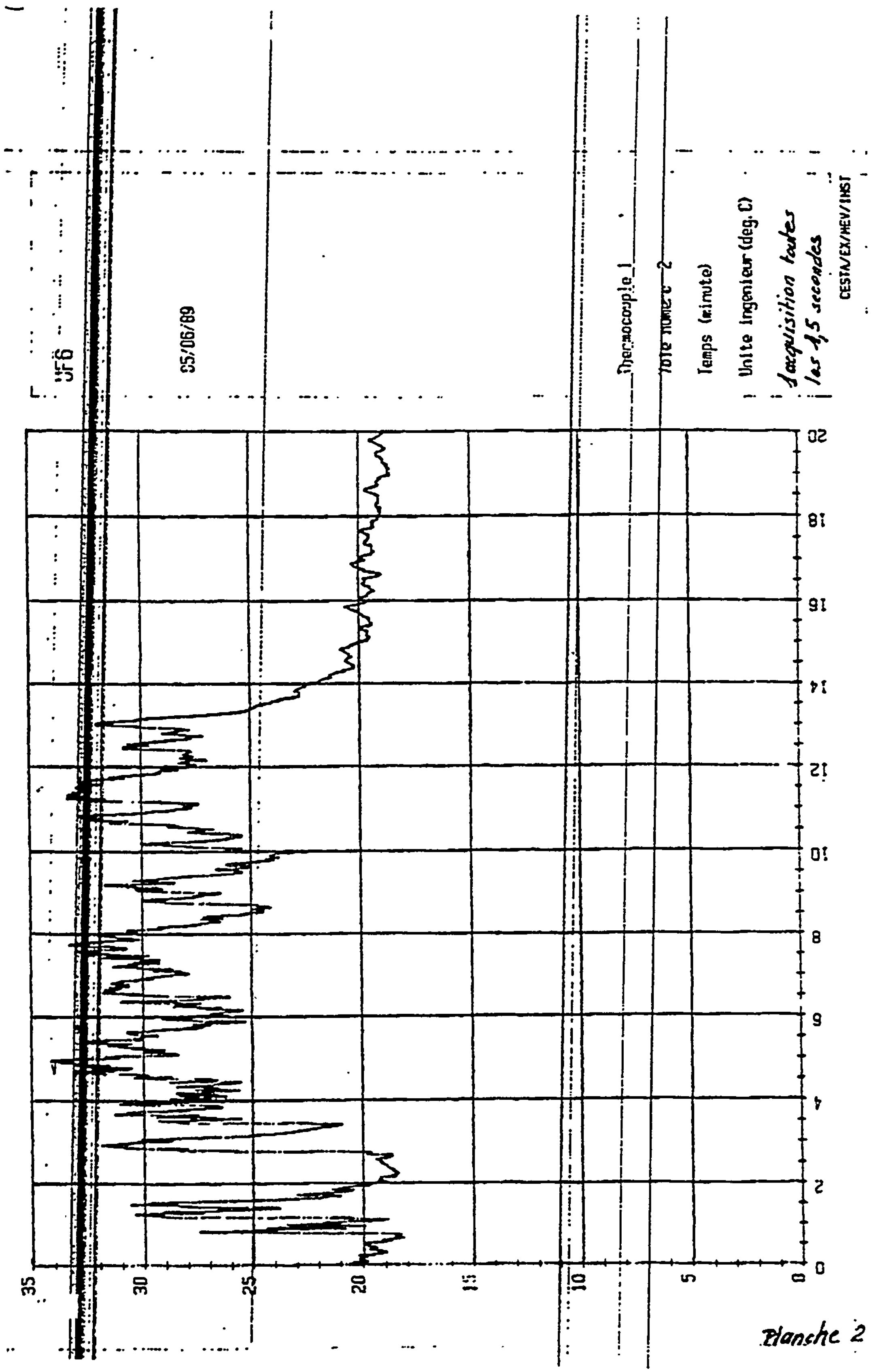
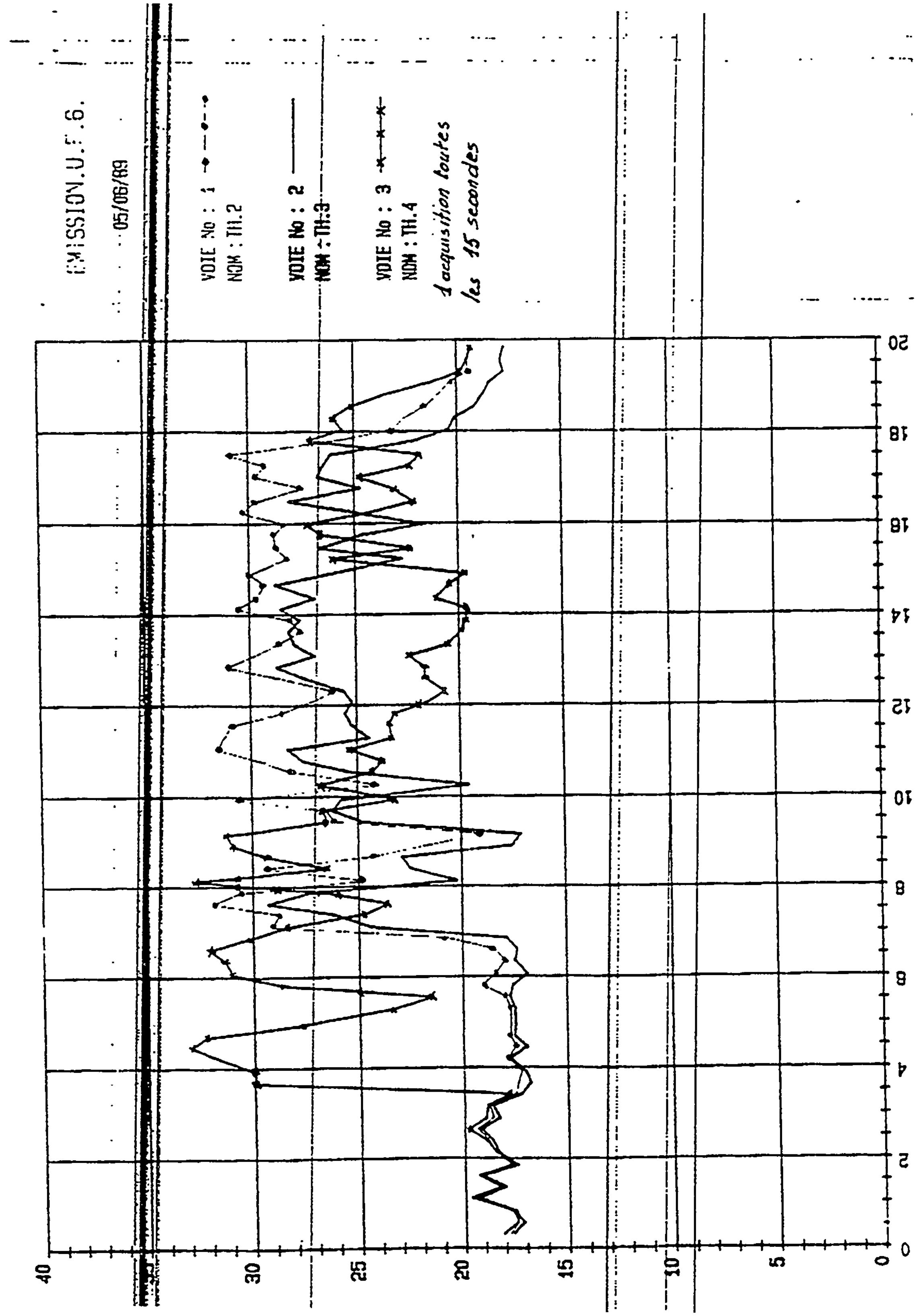


Fig. F.3. Temperature versus time for thermocouple 1.


EMISSION U.F.6.
05/06/89
VOIE No : 1
NOM : TH.2
VOIE No : 2
NOM : TH.3
VOIE No : 3
NOM : TH.4
1 acquisition toutes
les 15 secondes
0
5
10
15
20
25
30
35
40

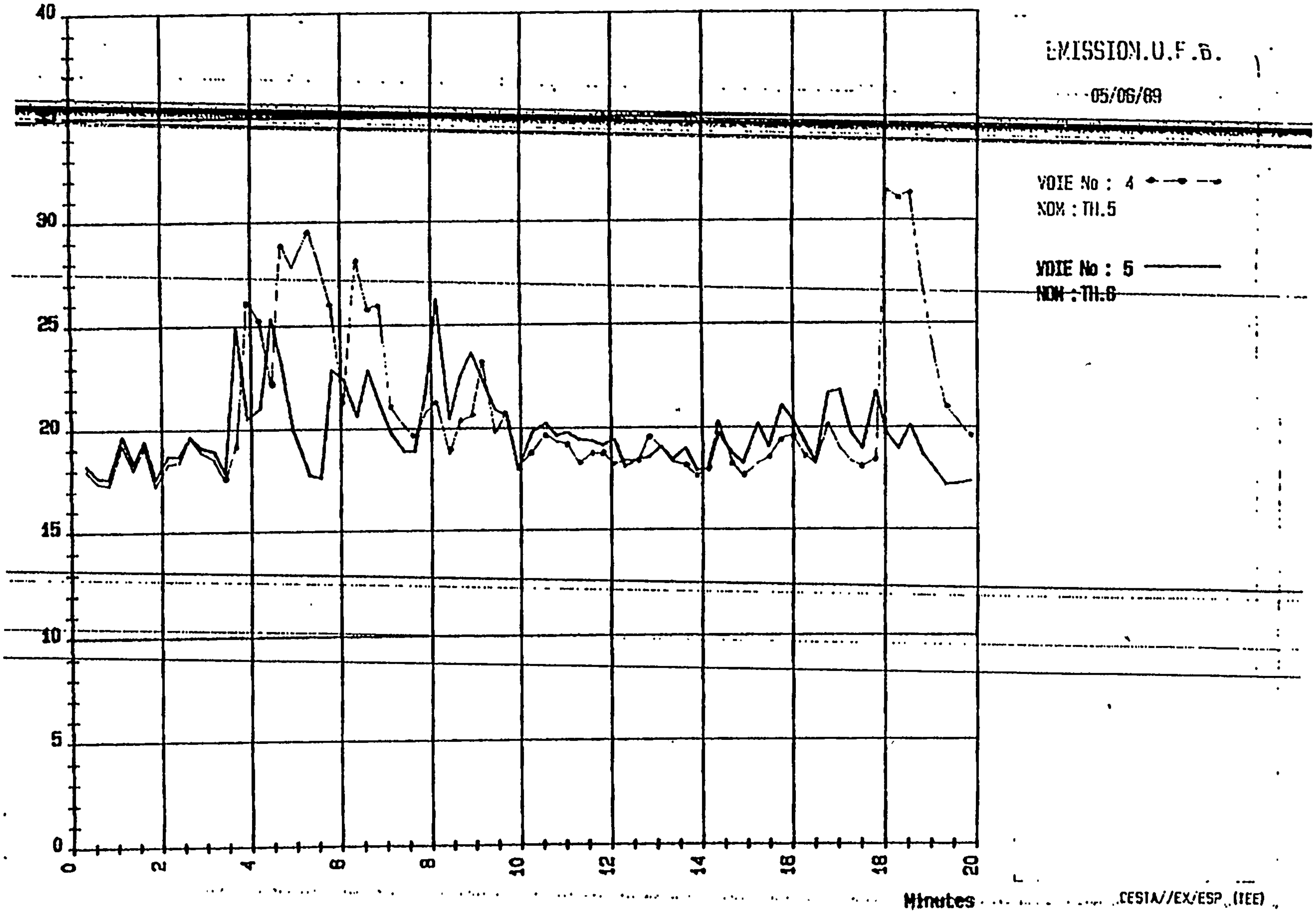
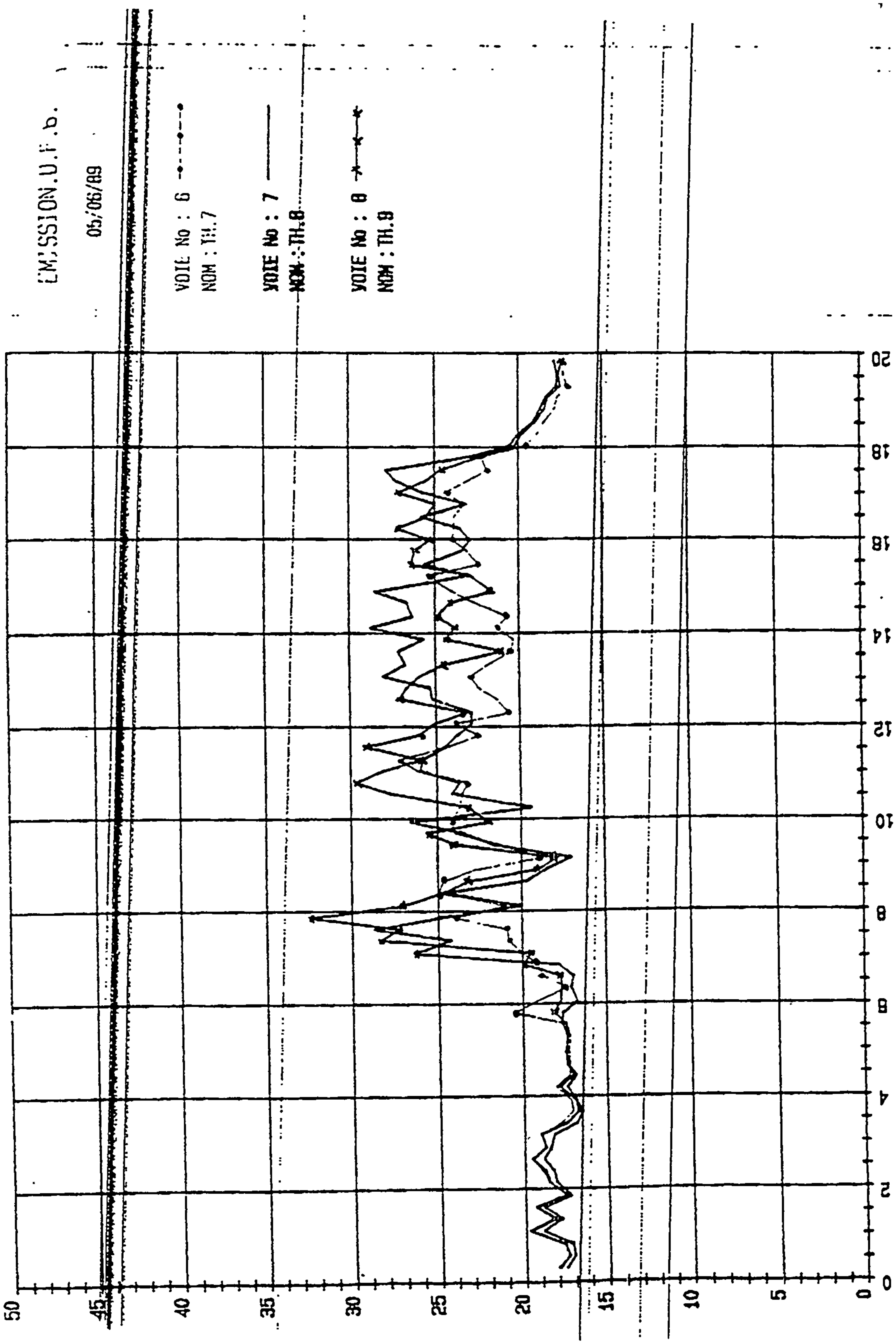


Fig. F.5. Temperature versus time for thermocouples 5 and 6.


EMISSION.U.F.b.
05/06/89
VOIE No : 6
NOM : TH.7
VOIE No : 7
NOM : TH.8
VOIE No : 8
NOM : TH.9
0
5
10
15
20
25
30
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45
50
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2
4
6
8
10
12
14
16
18
20

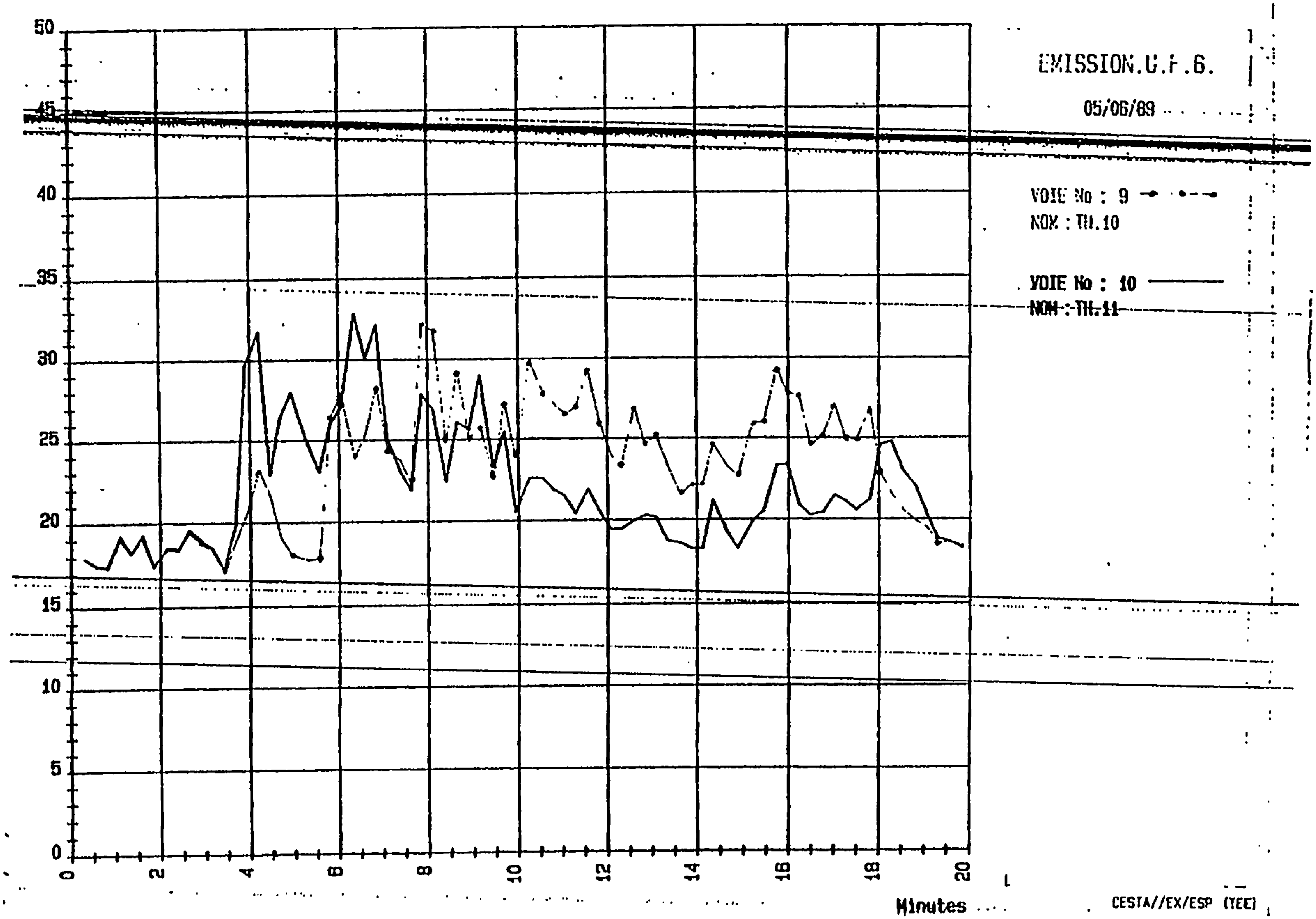
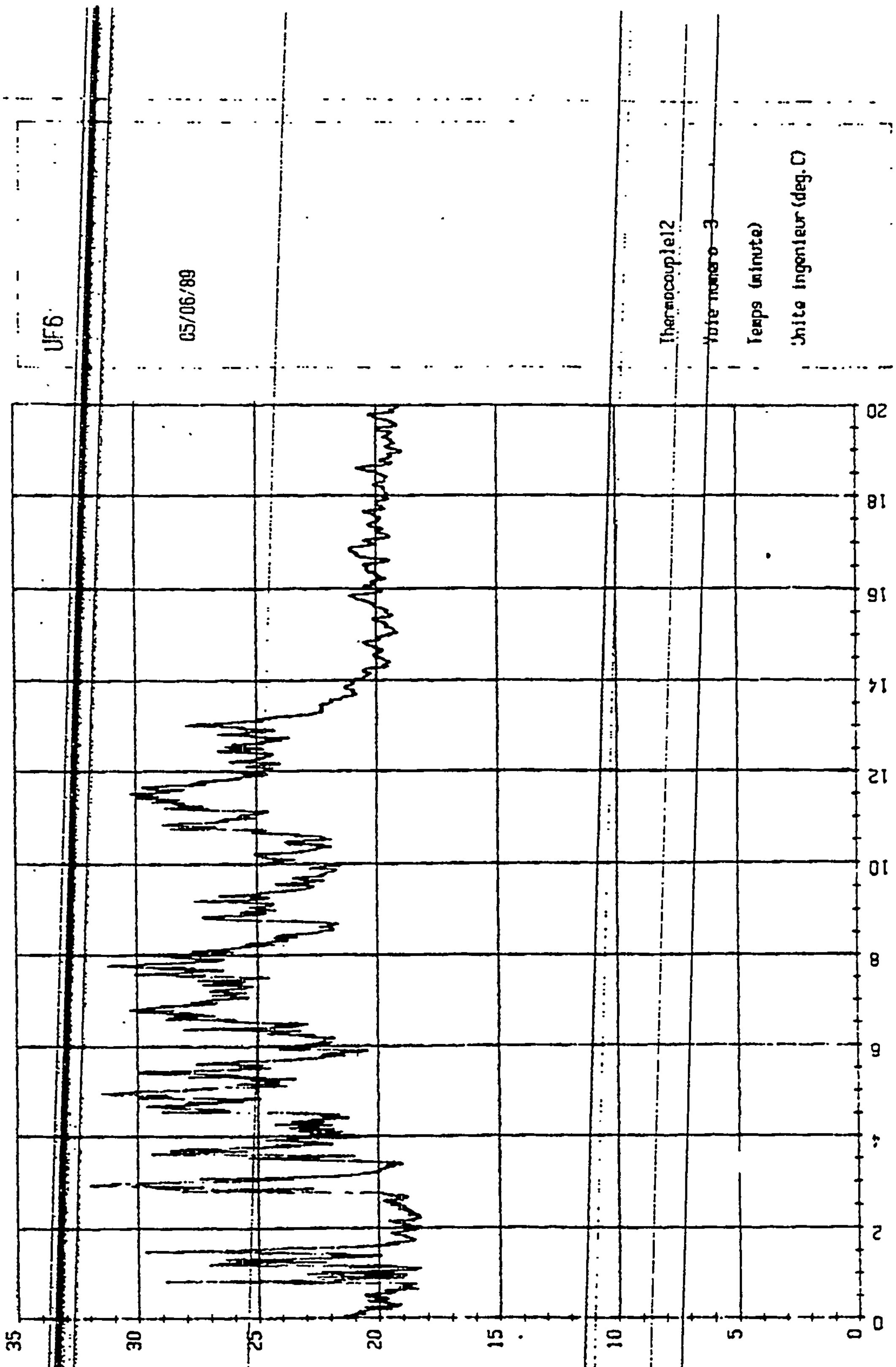


Fig. F.7. Temperature versus time for thermocouples 10 and 11.



UF6
05/06/89
Thermocouple12
Voie numero 3
Temps (minute)
Unite ingenieur (deg.C)
35
30
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20

Planche 7

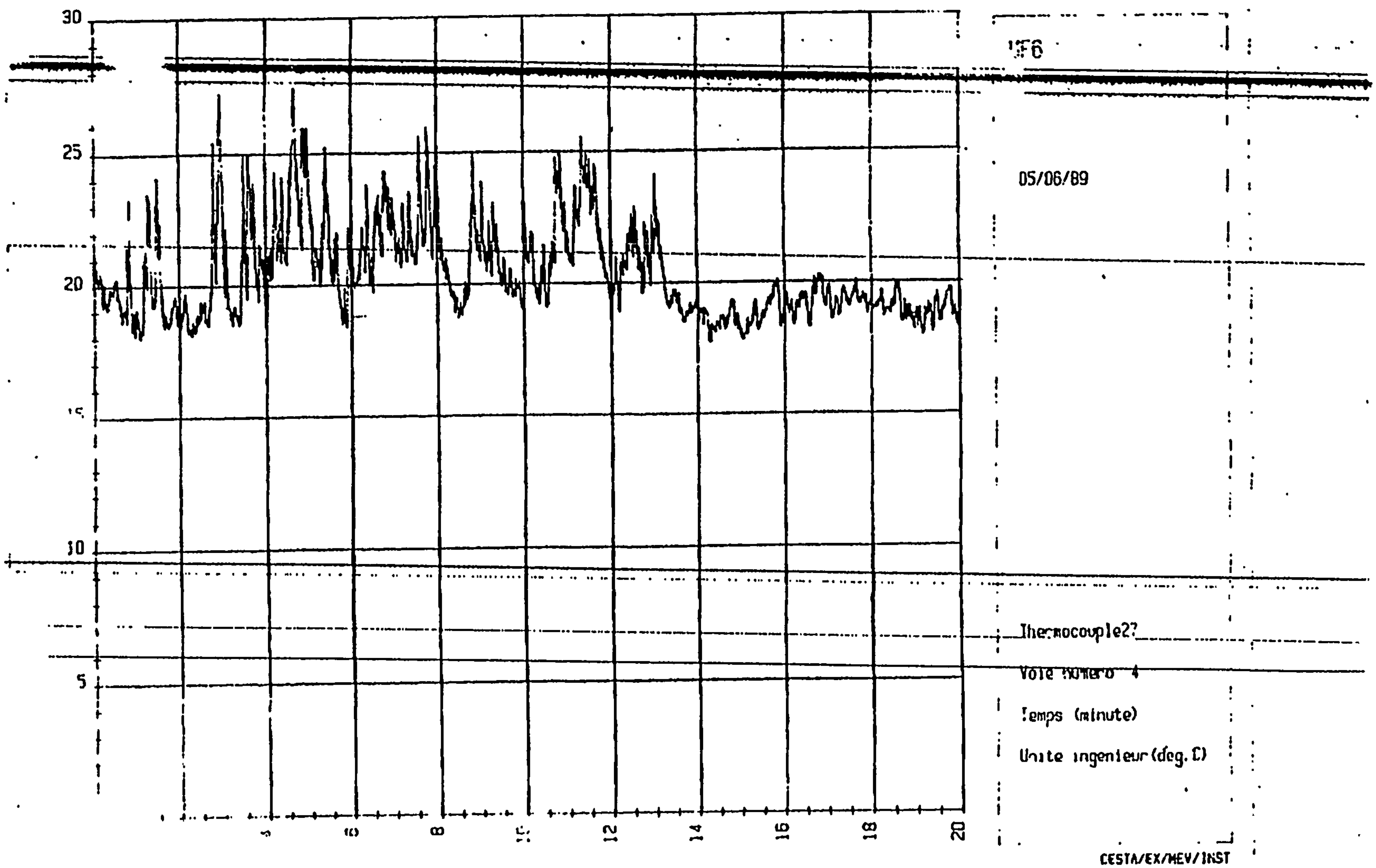


Fig. F.9. Temperature versus time for thermocouple 27.

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